# RP Note 51

# Site 68 Source Projector Facility

# Project Summary

F. P. Krueger

February 1985

Radiation Physics Note 51

# SITE 68 SOURCE PROJECTOR FACILITY
# PROJECT SUMMARY

F. P. Krueger

February 1985

The reconstruction of the source projector facility was performed as an attempt to solve the following problems with the existing facility:

1. Excessive (non-quantified) floor scatter beyond 2 meters source/detector distance.

2. Detector/source alignment not reproducible; and not remotely adjustable.

3. The source spectrum was "softened" by the lead attenuators used to obtain the necessary range of exposures.

4. The facility shielding proved insufficient to conform to ANSI N543-1974.

5. The facility operating procedures and security were inadequate.

6. No formal training was required for authorization to use the facility.

7. Facility documentation, including: security/warning devices; radiation surveys; facility calibration; exposure linearity and cross-section; were scattered, inadequate, or non-existent.

These problems were addressed in the following manner:

1. The source projector beam axis was raised to avoid intersection with the facility floor at close distances.

2. A chain driven carriage/track assembly with remote adjust and readout was installed parallel to the source beam axis. The carriage is equipped with positioning aids.

3. Two additional $^{137}Cs$ sources, in a single projector, were procured. These provide exposure rates of approximately 1/10 and 1/100 that of the existing source. The two projectors were mounted on a moveable carriage assembly running perpendicular to the detector carriage track. The desired exposure range can now be obtained without the use of attenuators.

4. The wood framed, plywood enclosure walls and door are now completely shielded with lead (1/16" minimum).

5. Detailed facility operating procedures were prepared and posted. Facility security was improved with increased administrative controls and improved interlocked warning devices.

6. Formal, documented training is now required for authorization to use the facility. A list of authorized personnel is posted at the facility.

7. Complete facility documentation has been completed and posted.

The Source Projector Facility Guide (Appendix A) describes in detail all features of the facility.

The facility was approved for use following successful tests of the interlock/warning systems and shielding leakage studies. Survey maps of the shielding leakage are posted at the facility.

Exposure linearity and beam cross-section studies were performed for the 137-8.1-1 source projector using TLD arrays (M. Ruhe). Consult Appendix D.

A four point, on-axis, linearity study was performed for the 137-8.1-1 source projector using a model 130 Victoreen R-Meter. The results of the R-Meter and TLD linearity studies are shown superimposed on Fig.1. The results indicate the facility is usable, without correction, beyond 3 meters source/detector distance.

The three projector facility sources were calibrated at 1 and 2 meters using the model 130 Victoreen R-Meter and results checked using a model 552 R-Meter and Dosimeter Corporation Model 862C characterized dosimeters (CDRD's).

The R-Meters and CDRD's were cal checked prior to performing the above tests. These checks were performed using NBS certified sources (137-5.4-1 and 137-5.5-1) in a fixed 1 meter, approximate free air, calibration fixture.

The precalibration checks, calibrations, and R-Meter linearity data are contained in Tables 1 & 2. The NBS certifications of the reference source and R-Meters, the original calibration data from the source projector manufacturer, and CDRD manufacturer, are contained in Appendix C.

The calibration values as determined by the Victoreen model 130 R-Meter were adjusted to 4-1-73, the baseline for the source projector calibration computer program. A tabular printout from this program is shown in Table 3. The exposure linearity values were normalized to the 1 meter calibration dose and plotted. The TLD linearity study results (Fig. 3) were similarly manipulated and superimposed with the R-Meter study (Fig.1).

The facility calibration information is updated by the IMAC team leader, via a computer program, at 6 month intervals. This tabular information is posted in WH-7E IMAC area, and at the Site 68 projector facility (Table 3).

## Calibration and Linearity Studies - (Summation)

TABLE 1 - 1 meter calibration fixture tests:

| Detector | Source | Distance | Est Dose | Data Pts. | Measured Dose | Std. Dev. | % From Est |
|---|---|---|---|---|---|---|---|
| Model 130 R-Meter | 137-5.5-1 NBS (9-82) | 1 M | 125 mR | 10 | 127 mR | .65 | + 1.6 |
| Model 130 R-Meter | 137-5.4-1 NBS (4-72) | 1 M | 125 mR | 5 | 127.9 mR | .6 | + 2.5 |
| CDRD's | 137-5.5-1 | 1 M | 160 mR | 20 | 161.3 | .5 | + 0.8 |
| CDRD's | 137-5.4-1 | 1 M | 160 mR | 15 | 160.4 | .7 | + 0.3 |

TABLE 2 - Beam projector source calibration/linearity:

| Source | Detector | Distance | Data Pts. | Measured Dose | Std. Dev. | Measured $\dot{D}$ | $\dot{D}$ Adjusted to 1 M | Comment |
|---|---|---|---|---|---|---|---|---|
| 137-8.1-1 | Model 130 R-Meter | .996 M | 5 | 132 mR | .4 | 28.46 R/Hr | 28.2 R/Hr | Cal |
| 137-8.1-1 | Model 552 R-Meter | 1 M | 5 | 1300 mR | 4.4 | 28.02 R/Hr | N/A | Check |
| 137-8.1-1 | CDRD's | 1 M | 14 | 163.4 | 1.5 | 28.01 R/Hr | N/A | Check |
| 137-8.1-1 | Model 130 R-Meter | 2 M | 5 | 131 mR | .5 | 7.04 R/Hr | 28.16 R/Hr | Check/ Lin |
| 137-8.1-1 | Model 552 R-Meter | 2 M | 2 | 1309 mR | | 7.05 R/Hr | 28.21 R/Hr | Check |
| 137-8.1-1 | CDRD's | 2 M | 15 | 162.5 | 1.1 | 6.882 R/Hr | 27.53 R/Hr | Check |
| 137-8.1-1 | Model 130 R-Meter | 3 M | 2 | 132.4 mR | | 3.18 R/Hr | 28.6 R/Hr | Lin |
| 137-8.1-1 | Model 130 R-Meter | 4 M | 2 | 140.7 | | 1.9 R/Hr | 30.35 R/Hr | Lin |
| 137-7.1-1 | Model 130 R-Meter | 1 M | 5 | 123.7 mR | .4 | 3.59 R/Hr | N/A | Cal |
| 137-7.1-1 | Model 552 R-Meter | 1 M | 3 | 1.25 R | .02 | 3.59 R/Hr | N/A | Check |
| 137-7.1-1 | CDRD's | 1 M | 6 | 156.3 mR | .8 | 3.5 R/Hr | N/A | Check |
| 137-6.1-1 | Model 130 R-Meter | 1 M | 5 | 122.02 | .34 | .457 R/Hr | N/A | Cal |
| 137-6.1-1 | CDRD's | 1 M | 3 | 156.9 | .5 | .448 R/Hr | N/A | Check |

FIGURE 1 - Source Projector Facility Linearity

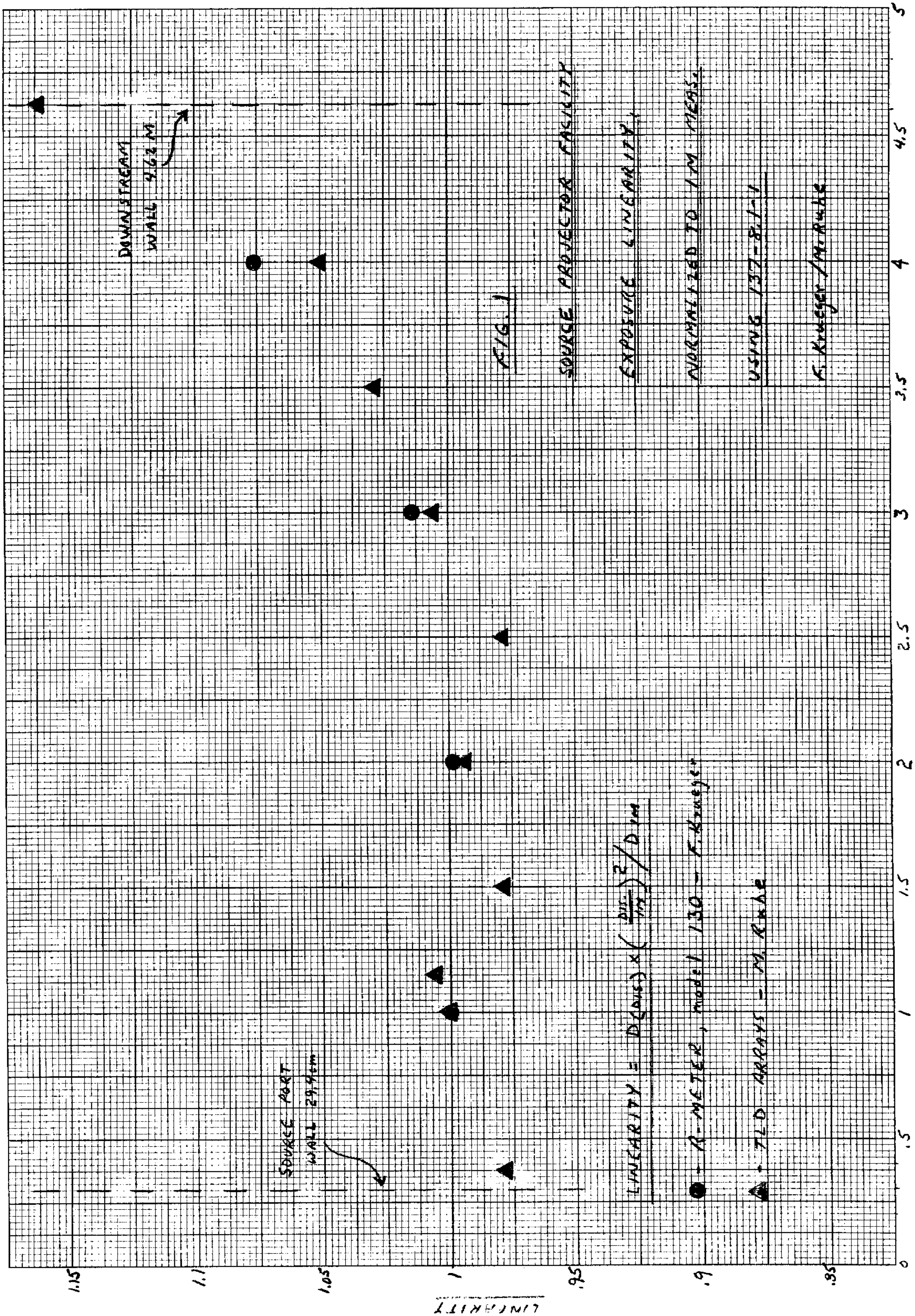


TABLE 3 - Source Projector Exposure Rates



| SOURCE | R/HR AT 1 METER |
|---|---|
| 8.1 | 27.8526 |
| 7.1 | 3.54334 |
| 6.1 | .451321 |

| DOSIMETER | TIME |
|---|---|
| 80R | 43 MINS. 5 SEC. |

DETECTOR DISTANCE (CM) FOR CONSTANT R/HR FOR JANUARY THRU JUNE 1985
********************************************************************

| R/HR | 8.1 | 7.1 | 6.1 |
|---|---|---|---|
| .05 | ..... | ..... | 300.4 |
| .06 | ..... | ..... | 274.2 |
| .07 | ..... | ..... | 253.9 |
| .08 | ..... | ..... | 237.5 |
| .09 | ..... | ..... | 223.9 |
| .1 | ..... | ..... | 212.4 |
| .2 | ..... | ..... | 150.2 |
| .3 | ..... | 343.6 | 122.6 |
| .4 | ..... | 297.6 | 106.2 |
| .5 | ..... | 266.2 | 95.0 |
| .6 | ..... | 243.0 | 86.7 |
| .7 | ..... | 224.9 | 80.2 |
| .8 | ..... | 210.4 | 75.1 |
| .9 | ..... | 198.4 | 70.8 |
| 1 | ..... | 188.2 | 67.1 |
| 2 | 373.1 | 133.1 | 47.5 |
| 3 | 304.6 | 108.6 | 38.7 |
| 4 | 263.8 | 94.1 | 33.5 |
| 5 | 236.0 | 84.1 | 30.0 |
| 6 | 215.4 | 76.8 | 27.4 |
| 7 | 199.4 | 71.1 | 25.3 |
| 8 | 186.5 | 66.5 | 23.7 |
| 9 | 175.9 | 62.7 | 22.3 |
| 10 | 166.8 | 59.5 | 21.2 |
| 20 | 118.0 | 42.0 | ..... |
| 30 | 96.3 | 34.3 | ..... |
| 40 | 83.4 | 29.7 | ..... |
| 50 | 74.6 | 26.6 | ..... |
| 60 | 68.1 | 24.3 | ..... |
| 70 | 63.0 | 22.4 | ..... |
| 80 | 59.0 | 21.0 | ..... |
| 90 | 55.6 | 19.8 | ..... |
| 100 | 52.7 | 18.8 | ..... |
| 200 | 37.3 | ..... | ..... |
| 300 | 30.4 | ..... | ..... |
| 400 | 26.3 | ..... | ..... |
| 500 | 23.6 | ..... | ..... |

# Appendix A

JL 12/85
Rev. 1

## SOURCE PROJECTOR FACILITY

I. Physical Description

A. The source projector facility is located in the southeast corner of the basement of Site 68. The room is enclosed, except for a single door. The walls are lined with lead to reduce scattered radiation outside of the enclosure.

B. The radioactive sources installed in the projectors are Cs 137: 137-6.1-1 (1.2 Ci), 137-7.1-1 (12 Ci), and 137-8.1-1 (135 Ci). 137-6.1-1 and 137-7.1-1 are mounted in a dual projector, and 137-8.1-1 is in a single projector.

C. The dose rates available range from about 25 mR/hr at 4 meters for 137-6.1-1 to about 400,000 mr/hr at 1 foot for 137-8.1-1.

D. The source projectors are mounted on a stand, outside of the enclosure, that allows either the single source (137-8.1-1) or the dual source (137-7.1-1 and 137-6.1-1) to be rolled into line with a port for projection into the inside of the enclosure.

E. A detector positioning stand is roller mounted to floor rails along the beam axis inside the enclosure. The stand can be moved on the rails, via a remote drive mechanism, to vary the distance from the source to the stand. This distance can be adjusted and readout from outside the enclosure.

F. ANSI standard N543-1974 for "enclosed" type gamma-ray source installations, from NBS handbook 114 was used as a guide.

II. Facility Safety Features

A. The sources are locked with their combination locks when the sources are not being used.

B. The door to the enclosure is locked with two lock-on-closing type spring latches. The construction of the latches is such that opening the door from the outside requires the use of two keys, one for each lock. The inside of the door has knobs to turn for exiting, in case the door is closed while someone is inside.

C. The source projectors cannot be opened from inside the enclosure.

D. Signs are posted at the facility with the following messages:

1. Projector Facility
2. Authorized personnel only
3. Radiation area
4. High radiation area inside
5. 400 R/hr at one foot when source is open
6. Emergency information
7. Area survey maps
8. This procedure

E. The facility is interlocked. The exposed source will close if any of the following conditions are met: the enclosure door is opened <u>or</u> the interlock "test" push button is pressed <u>or</u> the manual source "off" push button is pressed <u>or</u> the source control is switched to "off" position <u>or</u> the preset time expires in timed mode. The interlock will <u>not</u> prevent the sources from being held open manually.

A loud siren is activated inside the enclosure when the source is open and either the door is opened <u>or</u> the test push button is pressed. Independent of the interlock system, a bright rotating magenta beacon is activated inside the enclosure when the radiation level at the downstream wall of the enclosure is greater than or equal to one half of the dose rate of the smallest projector source at that point. A light display is provided to indicate the status of the door and projectors.

## III. Personnel Requirements

A. These sources are dangerous. The dose rate at 1 foot from 137-8.1-1 (exposed) is about 400 R/hr. Personnel exposure must be avoided.

B. Only personnel authorized by the Safety Section Head may operate the facility. The prerequisites for authorization are: attendance at the source training course, attendance at a demonstration of the source facility, and signing a document stating that they have read, and will obey these procedures.

C. The facility may be used with one or two operators. If the facility is to be used with one operator, <u>no</u> one else may participate in the experiment. If the facility is to be used with two operators, others may participate in the experiment. When using the two operator mode, both operators are required to be present when entering the enclosure, to be sure that the projectors are closed. Both operators are also required to be present when opening the projector, to make sure no one is in the enclosure, and that it is secure. During operation, the operator(s) must stay at Site 68, except as stated elsewhere in this section.

D. The operator(s) and all others taking part in the operation must wear: film badges, dosimeters, and digidoses.

E. All other personnel at Site 68 must wear film badges.

F. A sign stating that the projectors are being used must be posted across the inside vestibule door at the west entrance to Site 68. Signs are permanently posted at the entrances to the first floor southeast corner room stating that during facility operation the dose rate may approach 100 mR/Hr.

G. No one is allowed inside the projector enclosure when any of the sources is exposed.

H. The projector enclosure door must be closed and locked when a source is exposed.

I. In single operator mode, the operator must possess both enclosure keys. In two operator mode, each operator must possess an enclosure key.

J. Entry to the projector enclosure, while the facility is not in use, is permitted, provided that the person(s) make sure that the source projectors are in the closed position and are locked.

K. Unattended use of the facility during working hours is permitted under the following conditions: All other requirements of this procedure must be met. The operator(s) must keep both enclosure door keys, so that no one else can enter the enclosure. A sign must be posted at the facility indicating the operator(s) name(s), extension number(s), and pager number(s).

L. Unattended use of the facility during <u>off-hours</u> is permitted under the following conditions: Prior approval of the Safety Section Head is required. All preceding requirements must be met. In addition, the home phone number(s) of the operator(s) must be displayed on the sign, along with their name(s), extension(s), and pager number(s). Also, for this mode of operation, the Communications Center Dispatcher (x3414) must be notified of the situation, so that the Dispatcher can warn anyone needing to enter Site 68 of the danger. The Communications Center Dispatcher must also be notified when the operation is over.

M. Prior approval for variance from this procedure is required from the Safety Section Head.

IV. <u>Normal Operation</u>

A. This procedure deals only with the sources and the facility. It is assumed that the operators will make arrangements for any other equipment required.

B. All the rules set forth in this procedure must be obeyed.

C. The first step of operation of the source projector facility is to make sure that the sources are closed.

D. Place the "Projector Facility in use" sign across the vestibule door.

E. Take the enclosure keys from their storage location. If there are two operators, each operator gets a key.

F. After making sure the sources are closed, the operator(s) use the keys to enter the enclosure and setup the experiment.

G. Upon leaving the enclosure, the operator(s) search and secure the area, making sure that both door latches are locked.

H. Select the source to use by rolling it into line with the port.

I. Unlock the projector(s) to be used. Select timed or untimed operation. Pull up on the operating rod to expose the proper source. Do not open both projectors at the same time.

J. Look inside one of the viewing ports to make sure that the beacon is on. Press the siren alarm push button to make sure that the alarm is working. This will also close the exposed source. This test need only be done once, for each source, at the beginning of each operating period. If both projectors will be used, repeat steps H, I, and J for the other projector.

K. Adjust the source to detector distance by turning the hand crank and reading the tape measure located beneath the source stand.

L. Perform the exposure.

M. Close the source by pressing its "off" push button. In timed mode, the source will close by itself when timed out. Operator(s) make sure that both sources are closed.

N. Operator(s) may now use the keys to enter the enclosure. Use a survey meter to make sure that the sources are closed.

O. After the operation is done, close and lock both source projectors. Enter the facility and survey the area to verify that the source projectors are closed.

P. Close the facility door and put the enclosure keys back in their storage location.

Q. Remove the "Projector Facility in use" sign from the vestibule door.

## V. Check List

A. Before operation:

1. Make sure sources are closed.
2. Set up signs.
3. Have on film badges, dosimeters, digidoses.
4. Each operator take a key. Single operator keeps both keys.
5. Secure the facility.

B. At start of operation:

1. Make sure the source you are using is in line with the port.
2. Make sure beacon is on when source is open.
3. Make sure siren alarm test works and the sources close.

C. After operation:

1. Close and lock sources.
2. Enter the enclosure and make sure sources are closed, using a survey meter.
3. Close the facility door and return keys.
4. Remove signs put up previously.

## VI. General Responsibilities

A. The person ultimately responsible for the operation of the source projector facility is the Safety Section Head (Larry Coulson).

B. The person responsible for safety matters in the operation of the source projector facility is the Safety Section Safety Officer (Sam Baker).

C. The person responsible for alterations, repairs, modifications, and improvements to the source projector facility is the team leader of the Electronic Development Team (John Larson).

D. The person responsible for the source projectors is the Source Physicist (Alex Elwyn). Also, the source physicist is responsible for lock combinations and for all extra keys to the facility.

E. The IMAC team is responsible for testing the interlocks and warning devices every six months.

F. The operator(s) (users) of the facility assume responsibility for the safe operation of the facility during times of operation.

VII. Emergency Procedures

A. Close sources, if possible.

B. Leave immediate area.

C. Call 3131 for help.

I have read, and will follow the procedures for use of the Source Projector Facility (Revision 1).

| Print Name | I.D.# | Sign Name | Date |
|---|---|---|---|
| John Larson | 1612 | John Larson | 1-9-86 |
| Frederick P. Krueger | 1782 | Frederick P. Krueger | 1-9-86 |
| Fremont W. Hartman | 3678 | Fremont W. Hartman | 1-9-86 |
| Thomas S. Anderson | 721 | Thomas S. Anderson | 1-9-86 |
| THOMAS A. GOLASZEWSKI | 1871 | Thomas A. Golaszewski | 1-9-86 |
| Scott D. Hawke | 6396 | Scott D. Hawke | 1-10-86 |
| ~~Alex Elwyn~~ | ~~5702~~ | | |
| ALEX ELWYN | 5702 | Alex Elwyn | 1/10/86 |
| W Salsbury | 6834 | W Salsbury | 1/10/86 |
| W. S. Freeman ~~W. S. Freeman~~ | 5986 | W. S. Freeman | 1/10/86 |
| RICHARD ALLEN | 5559 | Richard Allen | 1/13/86 |
| PEDER YURISTA | 4699 | Peder M. Yurista | 1/15/86 |

Source Projector Facility Procedure (Revision 1)

Reviewed By: Samuel D. Baker — Safety Officer — Jan. 6, 1986 — Date

Approved By: Larry Coulson — Section Head — 1/9/86 — Date

# Site 68 Source Projector Facility Interlock/Warning Device

This device is to be used as a warning/status indicator for both beam projectors at Site 68. Both source projectors are interlocked.

## The Door Switches

The entrance door to the source facility has two normally open magnetic switches (providing redundancy) on the door frame. These are wired fail safe such that a cut switch wire simulates an open door. The switches are wired through an OR gate so that either switch opening will cause an open door condition. Switch #1 has a normally closed push button switch in series used for testing the system by simulating an open door.

## The Dual Source Switch

The dual source supplies 110 VAC from the sources bottom switch to K-2 coil when the source is not in use. When in use the 110 volts goes away and relay K-2 is opened causing an open source condition.

## Large Source Switch

The large source is wired identically to the dual source. However K-1 is used rather than K-2.

## Operation

When the source facility door and both sources are closed, this causes the green lamp to light. If during this condition the test button is pushed or the door is opened, the yellow lamp will light indicating an open door. When the door is closed and either or both sources are open the red lamp will light indicating a source is open. If at this time the test button is pushed or the door is open a loud whooper will sound. The dual source and/or the large source will then automatically close and turn off the whooper.

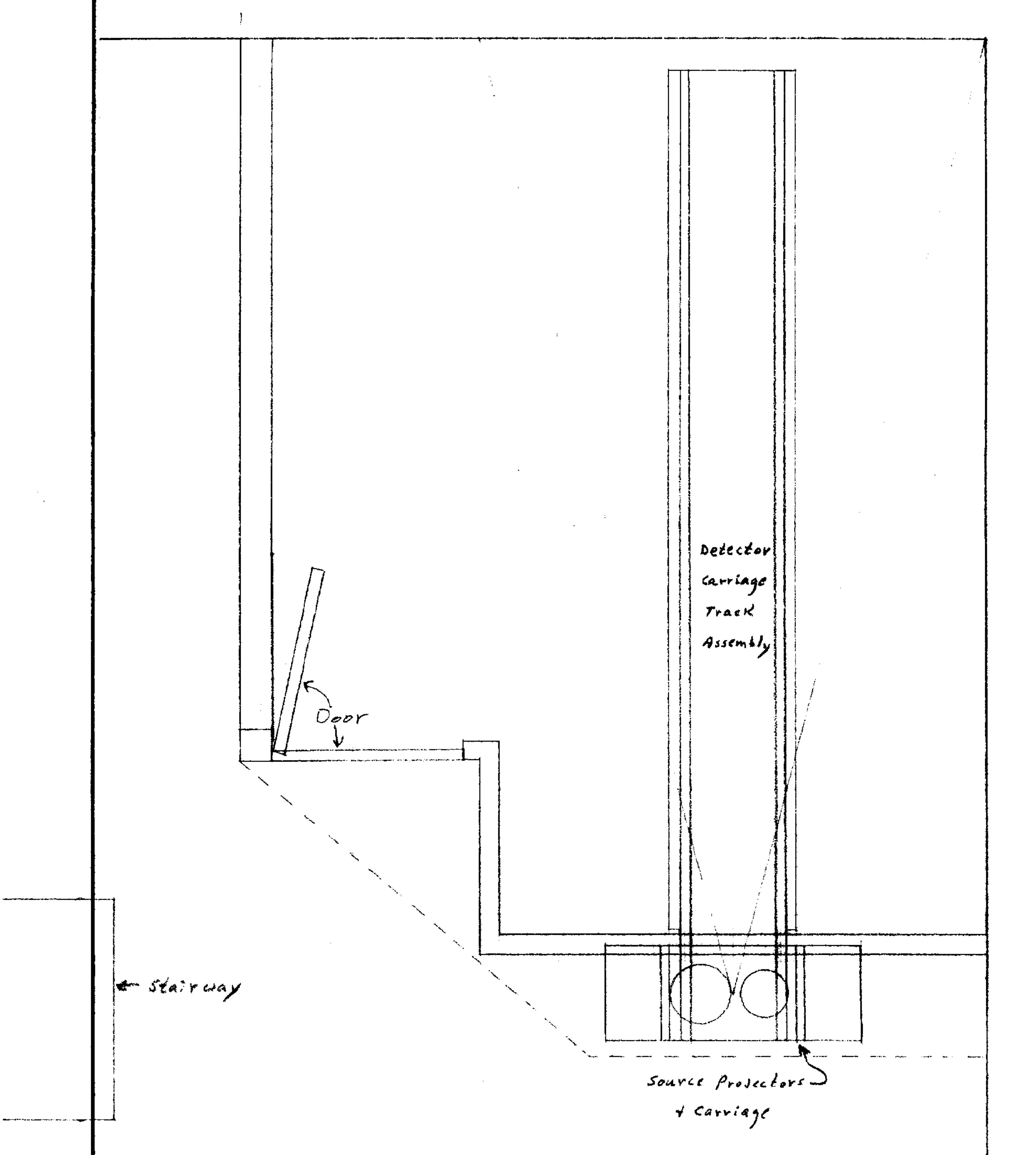
| APPENDIX B | SECTION Safety | PROJECT Projector | SERIAL-CATEGORY | PAGE 18 |
|---|---|---|---|---|

SUBJECT: Source Projector Facility Floor Plan

NAME: John Larson

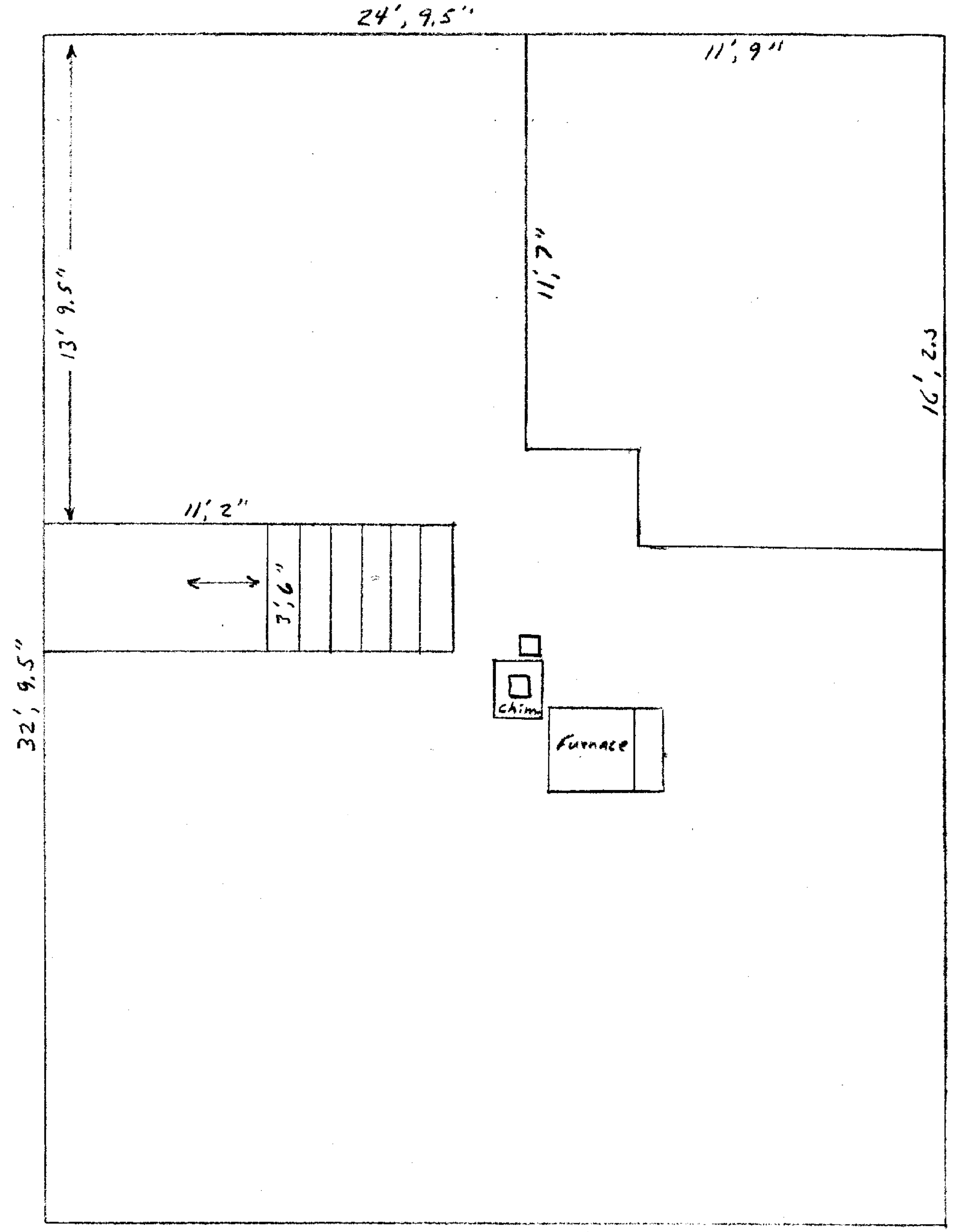
DATE: 6-13-84

REVISION DATE:



| APPENDIX B | SECTION | PROJECT | SERIAL-CATEGORY | PAGE |
|---|---|---|---|---|
| | SAFETY | 68 SOURCE | | 19 |

| SUBJECT | NAME | |
|---|---|---|
| Site 68 Basement Floor Plan | ?. P. Krueger | |
| | DATE | REVISION DATE |
| | 4-30-84 | |




SCALE: 1/4" = 1'

DG 7988/82
DB 806:188-190
TFN 228916
1982 Sep 23

APPENDIX C

Calibration Certificates

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, DC 20234

RECEIVED
OCT 20 1982
I.C.N. Pharmaceuticals

REPORT OF CALIBRATION

One Cesium-137 Source (FNAL 137-5.5-1)

Manufactured by ICN Pharmaceuticals, Inc.

Submitted by ICN Pharmaceuticals, Inc.
Irvine, CA 92715

Received on 1982 Aug 12

The cesium source is encapsulated in a stainless steel cylinder which is 20 mm long and 6 mm in diameter. The cylinder has a nut and threaded stud at one end. The cylinder is engraved as follows: 8-82, ICN, Cs 137, 500 MCI, 1407.

The source was calibrated for radiation emitted perpendicular to the long axis of the cylinder by intercomparison with cesium-137 sources which were calibrated in an open-air geometry. Details of the calibration procedure are given in: T. P. Loftus, "Standardization of Cesium-137 Gamma Ray Sources in Terms of Exposure Units (Roentgens)," J. Res. Nat. Bur. Stand. 74A, 1-6 (1970).

The exposure rate at one meter from the source on 1982 Sept 20 was found to be

$$10.8 \text{ nA m}^2/\text{kg} = 150 \text{ mR m}^2/\text{h}.$$

The attachments provide information concerning the units and the uncertainty in the exposure calibration. Information on technical aspects of this report may be obtained from T. P. Loftus, Radiation Physics C210, National Bureau of Standards, Washington, DC 20234, 301-921-2361.

Calibration supervised by T. P. Loftus T.P.L.

Report approved by R. Loevinger RL

For the Director
by

Elmer H. Eisenhower

Elmer H. Eisenhower
Deputy Chief, Radiation Physics Division
Center for Radiation Research
National Measurement Laboratory

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

1976 January

## Uncertainty in the Calibration of Gamma-Ray Sources

The calibration of small $^{137}Cs$ and $^{60}Co$ gamma-ray sources in terms of exposure is accomplished by comparison of the unknown source to a working standard source of the same type. The working standards are calibrated by comparison to a source which was measured in an open-air geometry using one of the NBS standard graphite cavity ionization chambers. The open-air standardization method is described in Reference 1. More recent information on the NBS standard cavity ionization chambers and on standardization of gamma-ray beams is given in Reference 2. The uncertainty associated with the Exposure Calibration given in the attached Report of Calibration is computed from the published values for the NBS standard chambers, 3 times the standard deviation of the mean for the source-comparison data, and estimated maximum errors for other identifiable factors in the standardization-comparison procedure. These data are summed in quadrature, as shown below, to give the uncertainty in the source exposure calibration.

| | |
|---|---|
| Standard chamber, including uncertainty in realizing the unit of exposure (from Reference 2) | 0.7% |
| Standardization of working standard source with standard chamber | 0.3 |
| Comparison of first working standard source with second working standard source | 0.5 |
| Comparison of working standard source with unknown source | 0.2 |
| Summation in quadrature | 0.9% |

1. T. P. Loftus "Standardization of Cesium-137 Gamma-Ray Sources in Terms of Exposure Units (Roentgens)," J. Res. Nat. Bur. Stand. (U.S.) 74A (Phys. and Chem), No. 1 (Jan-Feb 1970).

2. T. P. Loftus and J. T. Weaver. "Standardization of $^{60}Co$ and $^{137}Cs$ Gamma-Ray Beams in Terms of Exposure." J. Res. Nat. Bur. Stand. (U.S.) 78A (Phys and Chem), No. 4 (July-Aug 1974).

R. Loevinger

Robert Loevinger
Chief, Dosimetry Section
Center for Radiation Research

FNAL 137-5.4-1

MEASUREMENT OF ENCAPSULATED GAMMA-RAY SOURCES 22

| Radioisotope | Encapsulation | | | Exposure rate (mR/hm) | Measurement uncertainty (percent)* |
|---|---|---|---|---|---|
| | Material | Outer diameter (mm) | Wall thickness (mm) | mR/hr @ 1 meter | |
| Cobalt-60 Cylinder NBS No. 47402 Maker's No. W-636 | | | | 101 March 4, 1969 | ± 3% |
| Cesium-137 Cylinder NBS No. 47403 Maker's No. W-635 | | | | 131 Feb. 26, 1969 | ± 3% |

* Based on estimate of accuracy.

Test No. 198100(1&2)
March 17, 1969

J. L. SHEPHERD and Associates

703 So. Pacific Avenue, Glendale, California 91204 • 213/245-0187

Irradiation Equipment • Counting Systems • Nuclear Applications

# CALIBRATION CERTIFICATE

To : National Accelerator Laboratory
P. O. Box 500
Batavia, Illinois 60510

Source : ~~130Ci~~ $^{137}Cs$ in J. L. Shepherd and Associates Model A-0096 capsule.

Mounting : J. L. Shepherd and Associates Model 28-10 Beam Projector.

Instrument : Landsverk L-64 Roetgen meter. S. N. 438 using Model L-123 Chamber (O-1R) S. N. 648

Position : Centered in Beam port.

Distance : 1.00 meter

Output : 40.0 R/hr with 30° cone ; 33.0R/hr with 10°cone.

Date : March 14, 1973

J. L. Shepherd

J L SHEPHERD and Associates

Manufacturers Calibration of FNAL 137-7.1-1 and 137-6.1-1

740 Salem Street, Glendale, California 91203 • 213/245-0187

Irradiation & Calibration Equipment • Lead Shielding • Nuclear Applications

# CALIBRATION CERTIFICATE

TO: Fermi National Accelerator Laboratory P.O.#: 80756

| | | |
|---|---|---|
| SOURCE: | 12Ci $^{137}Cs$ ORNL<br>SK 193D S.N. S-12 | 1.2Ci $^{137}Cs$ 3M 4F6H<br>S.N. 3336 |

MOUNTING:
J.L. Shepherd & Associates Model 78-1M Calibrator, S.N. 9005

INSTRUMENT: Landsverk-64 Roentgen Meter, S.N. 438. This roentgen meter is calibrated by Dosimeters Incorporated and its calibration is directly traceable to National Bureau of Standards.

| | 12Ci | 1.2Ci |
|---|---|---|
| POSITION: | Centered in Beam Port | Centered in Beam Port |
| DISTANCE: | 1.00 meters from centerline of source | 1.00 meters from centerline of source |
| OUTPUT: | 3.96R/hr | 512mR/hr |

DATE: October 27, 1980

J.L. Shepherd

DG 7612/80
1981 MAR 18

NATIONAL BUREAU OF STANDARDS REPORT OF CALIBRATION

FERMILAB
BATAVIA, IL 60510

ELECTROMETER MODEL 570  SERIAL NUMBER 2910

| ELECTROMETER READING N (% FS) | POTENTIAL DIFFERENCE V(0)-V(N) (V) | RELATIVE SENSITIVITY S(N)/S(50) |
|---|---|---|
| 20 | 50.4 | 1.006 |
| 40 | 100.4 | 1.002 |
| 50 | 125.3 | 1.000 |
| 60 | 150.4 | 1.000 |
| 80 | 200.6 | 1.001 |
| 100 | 251.1 | 1.002 |

521 V = V(0) WAS THE POTENTIAL MEASURED FOR AN ELECTROMETER READING AT N = 0. THE VALUE OF V(0) GENERALLY SHOWS A LARGER VARIATION THAN V(0)-V(N). LONG-TERM MEASUREMENTS ON SIMILAR INSTRUMENTS INDICATE THAT THE PERCENT STANDARD DEVIATION OF V(0)-V(N) SHOULD NOT EXCEED 1.0%

THE ELECTROMETER SENSITIVITY IS S(N) = (V(0)-V(N))/N.

IF THE RELATIVE SENSITIVITY S(N)/S(50) DIFFERS SIGNIFICANTLY FROM UNITY, THE ELECTROMETER SCALE IS NON-LINEAR. IN THIS CASE, THE ELECTROMETER READING SHOULD BE MULTIPLIED BY THE APPROPRIATE RELATIVE SENSITIVITY.

IF THE CORRECTION FACTOR (COLUMN 4 OF THE CHAMBER CALIBRATION TABLE) WAS DETERMINED FOR A SCALE READING OTHER THAN 50%, THE RELATIVE SENSITIVITY SHOULD BE RENORMALIZED TO UNITY FOR THAT SCALE READING BEFORE CORRECTING FOR SCALE NON-LINEARITY.

CHECKED BY

DG 7612/80
1981 MAR 13

NATIONAL BUREAU OF STANDARDS REPORT OF CALIBRATION

FERMILAB
BATAVIA, IL 60510

VICTOREEN .25-R CHAMBER
MODEL 130 SERIAL NUMBER 10083
OPEN TO THE ATMOSPHERE WHEN TESTED
ELECTROMETER MODEL 570 SERIAL NUMBER 2910

| 1 | 2 | 3 | 4 | | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| BEAM CODE | CONST POTEN (KV) | EFFECT ENERGY (KEV) | CORRECTION FACTOR 22 DEG C AND 1 ATM CF | % FS | AL HVL (MM) | DIST (CM) | BEAM SIZE (MM) | EXP RATE (R/S) |
| CS137 | | 662 | .98 | 49 | | 195 | C373 | 5.8-04 |

DURING CALIBRATION THE CAVITY WAS POSITIONED IN THE CENTER OF THE BEAM WITH THE STEM PERPENDICULAR TO THE BEAM DIRECTION. THE MODEL NUMBER FACED THE SOURCE OF RADIATION.

CHECKED BY P. Lamperti

37

DG 7612/80
1981 MAR 18

NATIONAL BUREAU OF STANDARDS REPORT OF CALIBRATION

FERMILAB
BATAVIA, IL 60510

VICTOREEN 2.5-R CHAMBER
MODEL 552 SERIAL NUMBER X2910
OPEN TO THE ATMOSPHERE WHEN TESTED
ELECTROMETER MODEL 570 SERIAL NUMBER 2910

| 1<br>BEAM<br>CODE | 2<br>CONST<br>POTEN<br>(KV) | 3<br>EFFECT<br>ENERGY<br>(KEV) | 4<br>CORRECTION FACTOR<br>22 DEG C AND 1 ATM<br>CF | <br><br><br>% FS | 5<br>AL<br>HVL<br>(MM) | 6<br>DIST<br><br>(CM) | 7<br>BEAM<br>SIZE<br>(MM) | 8<br>EXP<br>RATE<br>(R/S) |
|---|---|---|---|---|---|---|---|---|
| CS137 | | 662 | 1.03 | 49 | | 195 | C406 | 5.6-03 |

DURING CALIBRATION THE CAVITY WAS POSITIONED IN THE CENTER OF THE BEAM WITH THE STEM PERPENDICULAR TO THE BEAM DIRECTION. THE MODEL NUMBER FACED THE SOURCE OF RADIATION.

CHECKED BY P. Lamperti

dosimeter CORPORATION 11286 Grooms Road / P.O. Box 42377 / Cincinnati, Ohio 45242 / (513)489-8100 / Telex 214-64



Manufacturers Calibration of Characterized Dosimeters

MODEL 862C CALIBRATION CERTIFICATE

Date:
Customer:

The Model 862C dosimeters identified by Serial Numbers below are warranted for hermeticity, precision, and accuracy as follows:

Hermeticity: After 16 hours exposure to <1mm Hg vacuum, the sensitivity of each dosimeter changed by less than 2.0% (3.2mR) @ 160mR dose.

Precision: During repeated exposures over a period of at least three months to a true $^{60}Co$ field of 160mR, variations between the means of groups of five calibration exposures did not exceed 1.0% (1.6mR).

Accuracy: The mean percent response of each dosimeter to a true $^{60}Co$ field of 160.0mR is presented below. The calibration of this field is directly traceable to NBS.

| S/N | % Response to True $^{60}Co$ Field |
|---|---|
| 4050002 | 161.2 |
| 4050003 | 159.6 |
| 4050004 | 159.0 |
| 4050005 | 160.6 |
| 4050006 | 158.6 |

Appendix D

# CHARACTERIZATION OF A GAMMA-RAY FIELD AT AN INSTRUMENT CALIBRATION FACILITY USING THERMOLUMINESCENT DOSIMETERS

Michael A. Ruhe

March, 1985

**ABSTRACT**

Harshaw TLD-700 thermoluminescent dosimeters were used to characterize the gamma ray fields at Fermilab's two instrument calibration facilities. At each location, exposure measurements were compared to values predicted by the inverse square law. Over most of the range of calibration, there was agreement with the assumed $1/d^2$ dependence to within ± 2.7%. But at certain locations, discrepencies from the inverse square law were as high as 18%, and are attributed to room scatter.

## INTRODUCTION

Health Physics instruments are calibrated by exposing a desired instrument in a radiation field of known intensity, and then comparing the instrument meter reading to the actual amount of exposure according to procedures outlined by the various regulatory agencies (Cember, p. 277). To obtain a desired exposure rate, it is common practice to select the distance between the radiation source and the instrument based on the source activity and an assumed inverse square law dependence. Thus,

$$\dot{x}_1 d_1^2 = \dot{x}_2 d_2^2 \quad , \text{ where}$$

$\dot{x}_1$ = exposure rate at location one

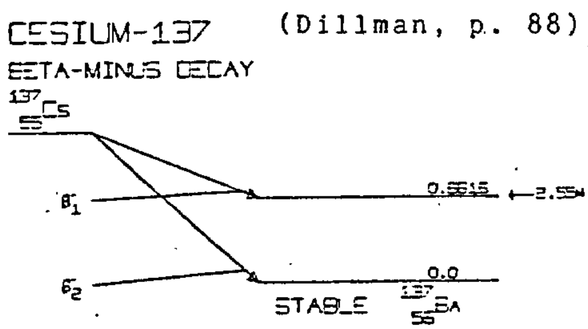
$d_1$ = distance from the source at location one

$\dot{x}_2$ = exposure rate at location two

$d_2$ = distance from the source at location two

However, in using the inverse square law, care must be exercised to approximate free-space geometry conditions. Scatter from the floor, walls, or ceiling of the room in which the calibration is performed will result in a slower decrease in the radiation exposure rate than would be predicted by the inverse square law. The American National Standards Institute (ANSI N323-1978) requires that such deviations be minimized.

At Fermilab, instrument calibrations are performed at two separate locations: The Wilson Hall 7-E Instrument Maintenance and Calibration facility (IMAC) and at the site 68 source projector facility. The source with the maximum activity used at IMAC is 370 mCi of Cs-137, while the activity of the site 68 source is nominally 130 Ci of the same isotope. The decay scheme for Cs-137 is shown below in Figure 1. The IMAC source is NBS-certified, while the site 68 source was previously cross-calibrated with an NBS source. In addition, the facility at site 68 recently underwent extensive renovation.




(Dillman, p. 88)

FIGURE 1

SPECIFIC GAMMA-RAY CONSTANT

for Cs-137*

$$\frac{.33\ R\text{-}m^2}{Ci\text{-}hr}$$

*from Radiological Health Handbook revised edition, 1970

In this study, the radiation fields at each facility, including both the previous and new setups at site 68, were examined using thermoluminescent dosimeters. Exposure measurements were normalized for time and distance to give the normalized dose, which is defined as:

$$\text{Normalized dose} = \frac{(\text{distance})^2 \times \text{measured dose}}{\text{irradiation time}}$$

The normalized dose was then compared to the theoretical values determined from the known source strength and the assumed inverse square law dependence.

# MATERIALS AND METHODS

## Thermoluminescent Dosimeters (TLD'S)

Thermoluminescent dosimeters have as their active elements materials which emit light when heated after having been exposed to radiation (Cember, p. 261). Absorption of energy from the radiation excites the atoms in the material, causing the electrons to "jump" from the ground state to an excited state. Some of the electrons return immediately to the ground state, while others are "trapped" in excited meta-stable states by impurities or imperfections in the material's crystalline lattice. The number of electrons trapped in these meta-stable states is proportional to the energy absorbed by the TLD during irradiation.

Unless additional energy is supplied, almost all of the trapped electrons remain in their excited states for long times after irradiation (Harshaw Chemical Company). When the crystals are heated, light is emitted as the electrons fall back to their ground state. This light is seen by a photomultiplier tube. Since the amount of light emitted by the crystal is proportional to the energy absorbed, measuring the integrated current from a photomultiplier tube gives the radiation dose absorbed by the TLD, once a suitable calibration factor has been established.

Lithium fluoride, enriched in the Lithium-7 isotope (99.93%) was used as the thermoluminescent material. The extruded ribbons of LiF were cut in the shape of rectangles by the manufacturer measuring 0.1 in. by 0.15 in., 0.035 in. thick, and weighing 25 mg each. This material was chosen since its response is known over a wide exposure range, with a linear response through 100 rads (Piesch et al, p. 563). Additionally, LiF TLD's exhibit a flat response for photon energies greater than 400 keV (Harshaw Chemical Company).

Typical Energy Response for LiF TLD's

(Harshaw Chemical Company)

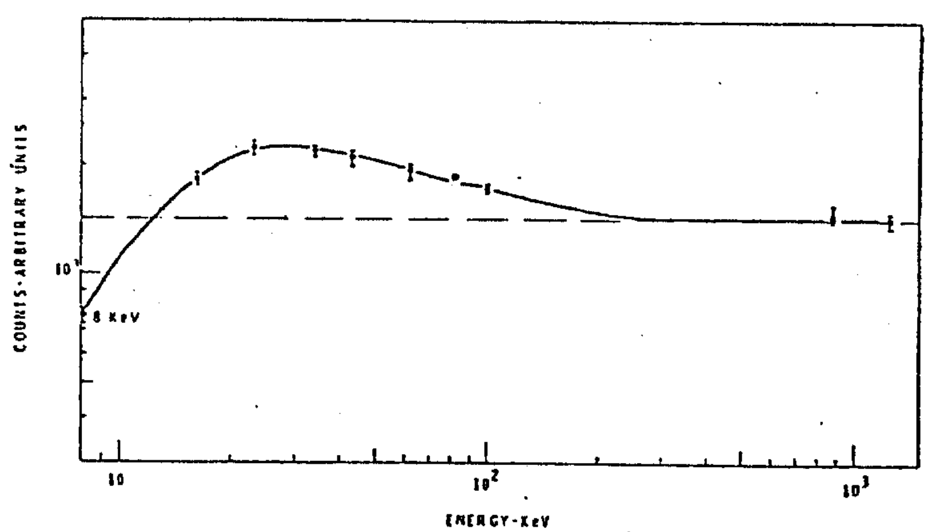



FIGURE 2

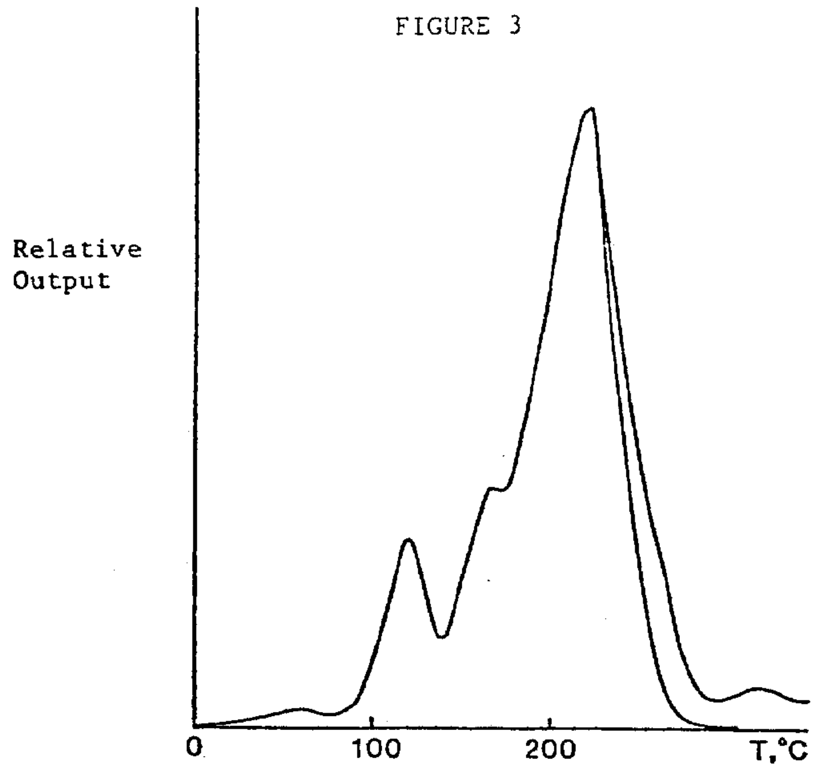
The 662 KeV photon emitted by Cs-137 lies within this range of linear response.

Despite their uniformity in size and mass, TLD chips have been found to vary in sensitivity in the range of 2-5% of a mean response (Cox, p. 6). This variation affects the reproducibility of a TLD chip's response to subsequent exposures of equal intensity. To better understand this variation, each chip was studied intensively beforehand at exposures of 1 R. Their responses were analyzed, and chips with nearly identical responses were grouped together in pairs. Paired responses to experimental irradiations were then averaged together to further reduce this statistical variation. Use of these techniques showed TLD reproducibility to be within ± 2% of a mean response. After each exposure the TLD's were heated to 104° C for 15 minutes prior to readout. This was necessary since only the high temperature glow peaks (T < 350° C) are used in dosimetry. The low temperature traps (T ≤ 100° C) tend to fade and therefore must be annealed away. A sketch of a glow curve for LiF TLD's is shown in figure 3.

Typical Glow Curve for LiF TLD's

(Lucus, page 3)

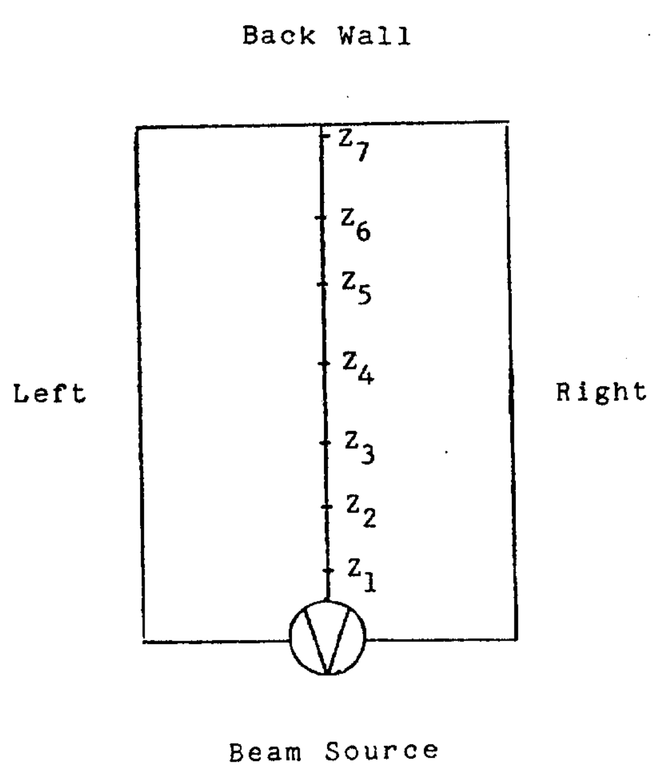
FIGURE 3




Actual readout consisted of heating the TLD's to 350° C and measuring the thermoluminescence, or light emitted, using a Harshaw model 2000D TLD reader and accompanying 2000B integrating picoammeter. Since the amount of light emitted is proportional to the amount of absorbed energy in the TLD for doses less than 100 rads, it was possible to determine the exposure level at each specific location in a radiation field. The TLD's were prepared for reuse by annealing them at 400° C for 15 minutes to erase their "memory" of the previous exposure. The chips were placed into 1/8 inch thick lucite holders prior to irradiation at each placement position.

Procedure

The procedure for all three experimental setups were similar in design, varying only in the placement of the TLD's relative to the source beam center line (figure 4) and the amount of exposure the TLD's were to receive at a given position. The first measurements taken at each experimental setup were along the beam center line, or z axis. TLD holders were hung individually from a ringstand at each desired position. Measurements were made individually along the axis, to eliminate any possible effects of absorption or ringstand "shadow" further down the center line. In addition, exposure times were adjusted for the TLD's at different distances from the source to provide a theoretical 1 R exposure.




Plan view, TLD positions along beam center line.

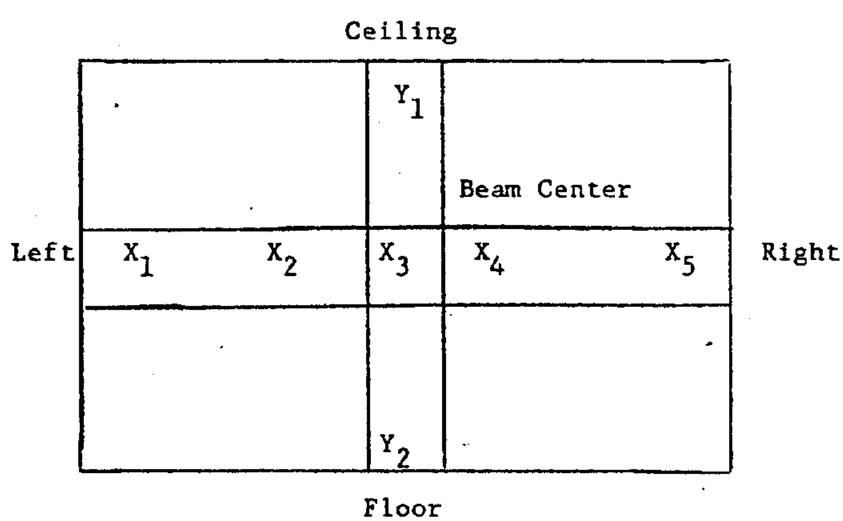
FIGURE 4

The second set of measurements involved placing the TLD's in a grid along vertical and horizontal lines transverse to the beam center line at selected distances from the source projector (figure 5). The TLD's were positioned at regular intervals from the ceiling to the floor, and from left to right at the beam height. Duct tape was used to hold the TLD's in their desired positions. Again, irradiation times were adjusted to provide the theoreticall R exposure. Distance corrections were made for TLD's positioned off of the center line.

<u>TLD Placement is a vertical</u>

<u>and horizontal grid</u>

FIGURE 5



Exposures conducted at the IMAC calibration table setup were normalized to 50 mR instead of 1 R as done at the site 68 source projector facility. This adjustment was necessary due to the much lower activity of that particular cesium source. Five pre-analysis calibration runs were conducted at that exposure level to verify TLD response reproducibility. Typical errors ranged from 1.1 to 4.8% with an average error of 2.7%.

<u>Errors</u>

The errors in the measurements derive primarily from three sources; the error in the time of irradiation, the error in TLD placement, and the error associated with the uncertainty in the TLD's themselves. Time measurements were made within ± 0.5 seconds, producing potential errors in the range of 0.01 to 0.8%. The TLD positioning errors ranged from 0.4 to 4.0% at site 68, and .04 to 3.4% at IMAC. This is since the placement uncertainty was approximately ± 1.0 cm at site 68, and ± 0.5 cm at IMAC.

As stated previously, individual TLD's have an inherent reproducibility uncertainty of between 2 to 5% for a given exposure level. The procedures used to minimize this variance have previously been described. However, for unexplained reasons, the TLD reader showed a downward drift in measuring the thermoluminescence of each subsequent calibration run at site 68. A linear regression analysis was performed to describe this phenonomen. The error at site 68, therefore, is based on the standard error of the estimate. A similar trend in TLD reader sensitivity was not observed during the IMAC trials.

## RESULTS AND DISCUSSION

See tables 1-5 and figures 6-11.

The inverse square law implies that a plot of the logarithm of the measured dose rate versus the logarithm of the distance from the source will produce a line with a slope of -2. For each experimental setup, this information was plotted (figures 6-8) and a least square fit line was drawn through the points. Even though the normalized dose increases substantially near the back wall as shown in figure 10, a straight line drawn through the data points minimizes this difference. In all three setups, the difference from the expected value of -2 was in the range of 0.8 to 2.0%, comparable to the intrinsic reproducibility of the TLD's themselves.

Of more interest is an analysis of the data which studies the deviations from the expected values given by an assumed inverse square dependence. With this viewpoint, the data taken at the site 68 source projector facility yields several clear trends. As was seen in figure 10, the normalized dose increased at positions close to the back wall. This effect was 13% along the wall in the former setup, and 18% in the present setup. This increase can be attributed to the effects of backscatter from that wall. Closer to the source projector, the previous setup showed an increase in normalized dose at positions approximately 3 meters from the source. This could be due to scattering from the floor since the beam cone intersected the floor near this location. The new setup did not show a comparable increase at the same distance since the beam center line height was repositioned approximately one foot higher from the floor.

The horizontal and vertical plots shown in figure 9 likewise demonstrate increased dose along the back wall due to backscatter. Similarly, positions situated towards the rear of the room close to the floor generally show increases from the effects of floor scatter. Further, in both the previous and new setups, there is a slight increase in normalized dose along the right wall, towards the rear of the room. This is probably the result of scattered radiation from that wall, since it is situated nearer to the beam center line than the left wall. And finally, the plots at z = 116.7 cm demonstrate the half angle of the radiation cone to be approximately 20°, in agreement with the source collimator design.

An analysis of the data accumulated at the IMAC calibration table yields less conclusive results. The left side of figure 11-A shows increased normalized dose compared to the right side. Why this occurred is not clear since the calibration table is not situated near any walls or other materials which could cause scattering. However, the z axis plot (figure 11-C) shows no deviation greater than 4% from $1/d^2$ along the entire length of the axis. And finally, both the horizontal and vertical plots demonstrate the half angle of the radiation cone to be 15°.

## CONCLUSIONS

The data present a consistent picture of the intensity of the radiation field along the beam center line in all three experimental setups. This is important since instrument calibration is normally performed only along this line. Should a technician responsible for calibrating radiation instruments deem the floor or wall scatter components too severe, he can determine the appropriate correction factors from the data. In practice this would not be necessary since instrument calibrations would not be conducted in locations where the radiation intensity did not fall off with the inverse square law. Instead, adjustments in exposure time would be made to obtain a desired level of exposure. Most importantly, however, this study provides documentation of the characteristics of the radiation fields at both of Fermilab's operational calibration facilities.

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TABLE 1

Site 68 - Previous Setup

| d (m) | Dose Rate (R/min) | Best fit equation |
|---|---|---|
| 0.50 | 1.82 | |
| 1.00 | .45 | $\log D = (-1.96)\log d - 0.34$ |
| 1.17 | .33 | |
| 1.50 | .20 | |
| 2.00 | .12 | % differences from expected |
| 2.50 | .08 | |
| 3.00 | .05 | |
| 3.50 | .04 | |
| 4.00 | .03 | 2.0% |
| 4.50 | .03 | |
| 4.90 | .02 | |

Site 68 - New Setup

| d (m) | Dose Rate (R/min) | Best fit equation |
|---|---|---|
| 0.50 | 1.76 | |
| 1.00 | .44 | |
| 1.17 | .40 | $\log D = (-1.98)\log d - 0.34$ |
| 1.50 | .20 | |
| 2.00 | .11 | % difference from expected |
| 2.50 | .07 | |
| 3.00 | .05 | |
| 4.00 | .03 | 1.2% |
| 4.63 | .02 | |

IMAC Table Setup

| d (cm) | Dose Rate (mR/min) | Best fit equation |
|---|---|---|
| 15 | 70.85 | |
| 25 | 24.05 | $\log D = (-2.02)\log d - 4.21$ |
| 50 | 5.95 | |
| 75 | 2.78 | % difference from expected |
| 100 | 1.42 | |
| 125 | 1.00 | |
| 145 | .72 | 0.8% |

TABLE 2

Site 68 - Previous Setup

Distance from source along center line = 1.17m
Irradiation time = 3.00 minutes

| Dose (R) | Distance from Source to TLD (m) | | θ | Normalized Dose |
|---|---|---|---|---|
| 0.07 | Left | 1.13 | 23.2 | 0.04 |
| .88 | Left | 1.20 | 14.4 | .42 |
| .98 | CL | 1.17 | 0.0 | .44 |
| .90 | Rt | 1.21 | 14.4 | .44 |
| .25 | Rt | 1.27 | 23.2 | .13 |
| .68 | Up | 1.23 | 18.4 | .34 |
| .95 | Up | 1.82 | 9.2 | .44 |
| .95 | Down | 1.19 | 10.3 | .45 |
| .70 | Down | 1.24 | 19.5 | .36 |

d = 3.00m
t = 20.00 minutes

| Dose (R) | Distance from Source to TLD (m) | | θ | Normalized Dose |
|---|---|---|---|---|
| 0.84 | Left | 3.15 | 18.4 | .41 |
| .99 | Left | 3.04 | 9.5 | .46 |
| 1.04 | CL | 3.00 | 0.0 | .47 |
| 1.02 | Rt | 3.04 | 9.5 | .47 |
| .86 | Rt | 3.15 | 18.4 | .43 |
| .43 | Up | 3.23 | 21.6 | .42 |
| .88 | Up | 3.10 | 14.7 | .22 |
| .99 | Up | 3.02 | 7.4 | .45 |
| 1.06 | Floor | 3.03 | 7.8 | .49 |

d = 4.91m (back wall)
t = 55.50 minutes

| Dose (R) | Distance from Source to TLD (m) | | θ | Normalized Dose |
|---|---|---|---|---|
| 1.05 | Left | 5.13 | 17.0 | .50 |
| 1.16 | Left | 5.01 | 11.5 | .53 |
| 1.21 | Left | 4.94 | 5.8 | .53 |
| 1.27 | CL | 4.91 | 0.0 | .55 |
| 1.25 | Rt | 4.93 | 4.7 | .55 |
| 1.20 | Rt | 4.97 | 9.3 | .54 |
| 1.17 | Rt | 5.05 | 13.7 | .54 |
| 1.00 | up | 5.16 | 17.9 | .48 |
| 1.17 | Up | 5.05 | 13.6 | .51 |
| 1.21 | Up | 4.97 | 9.1 | .54 |
| 1.24 | Up | 4.93 | 4.5 | .54 |
| 1.20 | Floor | 4.93 | 4.8 | .53 |

TABLE 3

Site 68 - New setup

Distance from source along center line = 1.17m
Irradiation time = 3.00 minutes

| Dose (R) | Distance from source to TLD (m) | | θ | Normalized Dose |
|---|---|---|---|---|
| 0.08 | Left | 1.27 | 23.2 | 0.04 |
| .93 | Left | 1.21 | 14.4 | .45 |
| 1.01 | CL | 1.17 | 0.0 | .46 |
| .90 | Rt | 1.21 | 14.4 | .44 |
| .06 | Rt | 1.27 | 23.2 | .03 |
| .04 | Up | 1.31 | 27.2 | .02 |
| .98 | Up | 1.18 | 9.7 | .45 |
| .85 | Down | 1.22 | 17.1 | .42 |
| .03 | Down | 1.37 | 31.7 | .02 |

d = 3.00m
t = 20.00 minutes

| Dose (R) | Distance from source to TLD (m) | | θ | Normalized Dose |
|---|---|---|---|---|
| 0.79 | Left | 3.16 | 18.4 | 0.40 |
| .94 | Left | 3.04 | 9.5 | .43 |
| .97 | CL | 3.00 | 0.0 | .44 |
| .93 | Rt | 3.04 | 9.5 | .43 |
| .82 | Rt | 3.16 | 18.4 | .41 |
| .84 | Up | 3.11 | 14.9 | .41 |
| .94 | Up | 3.03 | 7.6 | .43 |
| .98 | Down | 3.03 | 7.6 | .44 |
| .99 | Floor | 3.09 | 14.0 | .47 |

d = 4.63 m
t = 47.00 mintues

| Dose (R) | Distance from source to TLD (m) | | θ | Normalized Dose |
|---|---|---|---|---|
| 0.20 | Left | 4.86 | 18.0 | 0.46 |
| 1.02 | Left | 4.73 | 12.2 | .49 |
| 1.11 | left | 4.65 | 6.2 | .51 |
| 1.13 | CL | 4.63 | 0.0 | .51 |
| 1.13 | Rt | 4.64 | 5.0 | .52 |
| 1.12 | Rt | 4.69 | 9.9 | .53 |
| 1.08 | Rt | 4.78 | 14.6 | .52 |
| 1.01 | Up | 4.78 | 14.6 | .49 |
| 1.05 | Up | 4.69 | 9.8 | .49 |
| 1.10 | Up | 4.64 | 5.0 | .50 |
| 1.13 | Down | 4.64 | 5.0 | .52 |
| 1.09 | Floor | 4.68 | 8.9 | .51 |

TABLE 4

Site 68 - Previous Setup

| d*(m) | Dose(R) | Irradiation Time (min) | Normalized Dose |
|---|---|---|---|
| 0.50 | 1.82 | 1.00 | 0.46 |
| 1.00 | 1.13 | 2.51 | .45 |
| 1.17 | .99 | 3.00 | .45 |
| 1.50 | 1.01 | 5.00 | .46 |
| 2.00 | 1.05 | 9.00 | .47 |
| 2.50 | 1.06 | 14.00 | .47 |
| 3.00 | 1.07 | 20.00 | .48 |
| 3.50 | 1.04 | 27.00 | .47 |
| 4.00 | 1.06 | 35.50 | .48 |
| 4.50 | 1.10 | 45.00 | .50 |
| 4.91 (wall) | 1.84 | 55.50 | .51 |

Site 68 - new setup

| d*(m) | Dose(R) | Irradiation time (min) | Normalized Dose |
|---|---|---|---|
| 0.50 | 1.76 | 1.00 | 0.44 |
| 1.00 | 1.10 | 2.50 | .44 |
| 1.17 | 1.19 | 3.00 | .45 |
| 1.50 | .97 | 5.00 | .44 |
| 2.00 | 1.00 | 9.00 | .44 |
| 2.50 | .98 | 14.00 | .44 |
| 3.00 | 1.00 | 20.00 | .45 |
| 3.50 | 1.03 | 27.00 | .47 |
| 4.00 | 1.05 | 35.50 | .47 |
| 4.63 (wall) | 1.15 | 47.00 | .52 |

*along Z axis

TABLE 5

IMAC Table setup

distance from source along center line = 50 cm
Irradiation time = 8.50 minutes

| Dose (mR) | Distance from source to TLD (cm) | | θ | Normalized Dose |
|---|---|---|---|---|
| 7.7 | Left | 53.9 | 21.8 | 2600 |
| 48.6 | Left | 51.0 | 11.3 | 14900 |
| 50.0 | CL | 50.0 | 0.0 | 14900 |
| 45.2 | Rt | 51.0 | 11.3 | 13800 |
| 8.3 | Rt | 53.9 | 21.8 | 2800 |
| 7.6 | Up | 57.1 | 28.8 | 2900 |
| 6.9 | Up | 53.0 | 19.3 | 2300 |
| 48.4 | Up | 50.6 | 8.5 | 14600 |
| 52.1 | Floor | 50.6 | 8.5 | 15300 |

d = 100 cm
t = 32.7 minutes

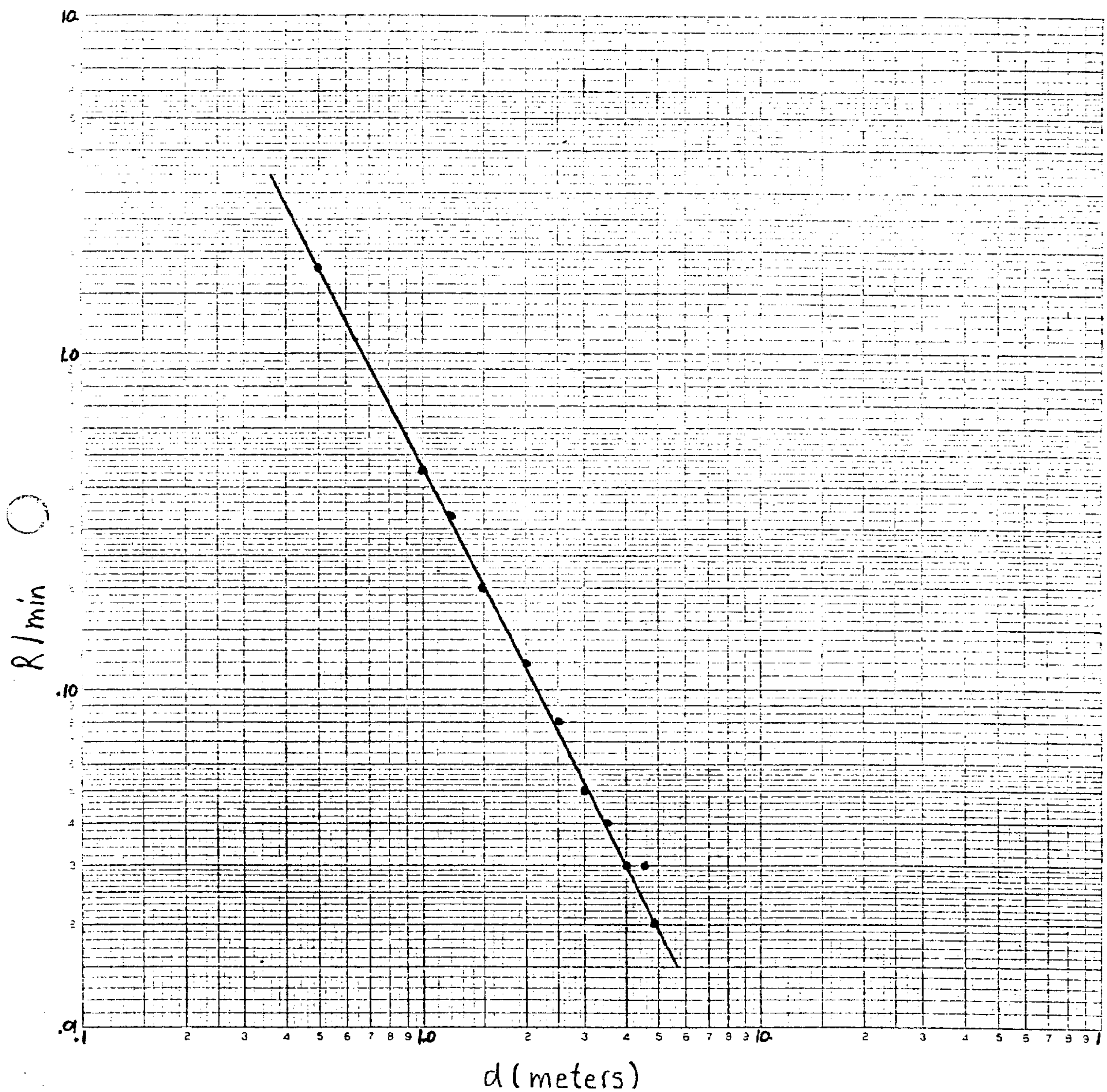
| Dose (mR) | Distance from source to TLD (cm) | | θ | Normalized Dose |
|---|---|---|---|---|
| 15.7 | Left | 106 | 19.3 | 5400 |
| 49.4 | Left | 102 | 11.3 | 15700 |
| 51.5 | CL | 100 | 0.0 | 15700 |
| 44.1 | Rt | 102 | 11.3 | 1400 |
| 10.0 | Rt | 106 | 19.3 | 3400 |
| 9.8 | Up | 107 | 20.6 | 3400 |
| 45.2 | Up | 103 | 12.7 | 14500 |
| 48.3 | Up | 100 | 4.3 | 14900 |
| 51.3 | Floor | 100 | 4.3 | 15800 |

| $d^*$ (cm) | Dose (mR) | Irradiation time (min) | Normalized Dose |
|---|---|---|---|
| 15 | 70.9 | 1.00 | 15900 |
| 25 | 48.1 | 2.00 | 15000 |
| 50 | 50.6 | 8.50 | 14900 |
| 75 | 51.5 | 18.50 | 15700 |
| 100 | 46.4 | 32.67 | 14200 |
| 125 | 51.5 | 51.50 | 15600 |
| 145 | 49.3 | 68.67 | 15100 |

*along z axis

FIGURE 6

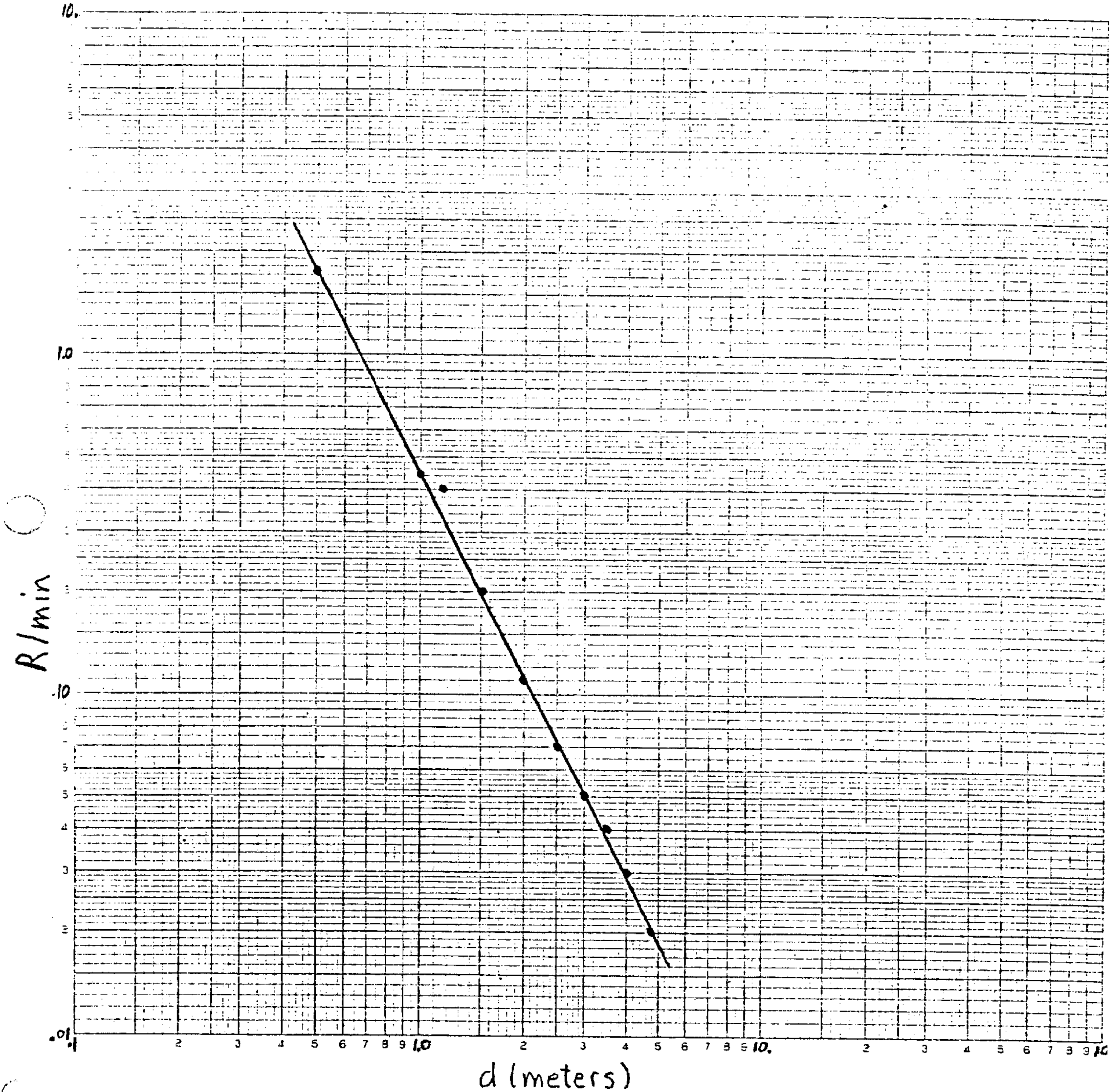
PLOT OF DOSE RATE VERSUS DISTANCE FROM THE SOURCE AT
SITE 68 (PREVIOUS SETUP)




Full Logarithmic, 3 × 3 Cycles

## FIGURE 7

PLOT OF DOSE RATE VERSUS DISTANCE FROM THE SOURCE AT SITE 68 (NEW SETUP)




Full Logarithmic, 3 × 3 Cycles

FIGURE 8

PLOT OF DOSE RATE VERSUS DISTANCE FROM THE SOURCE

AT IMAC

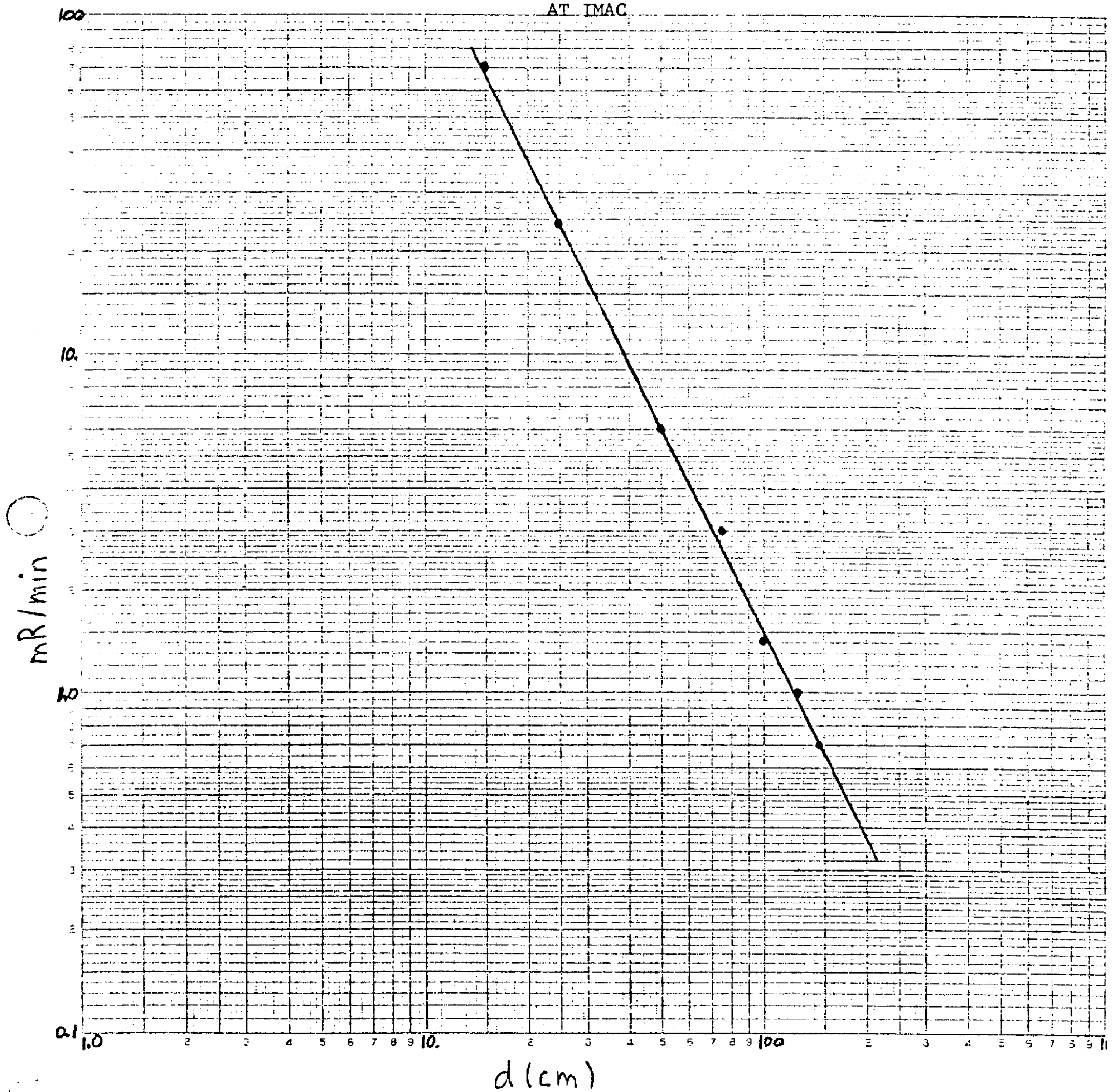
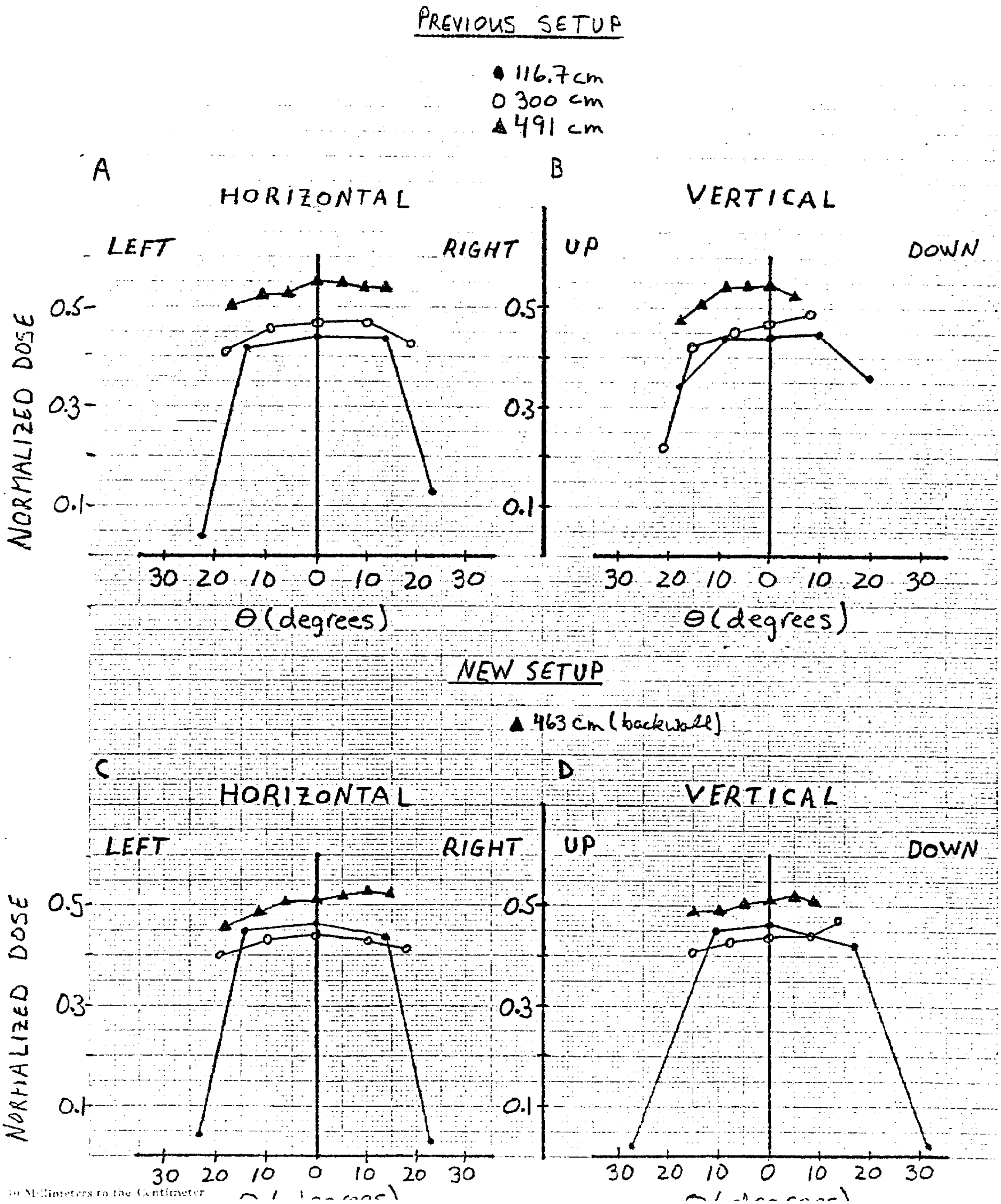


FIGURE 9

DEVIATIONS FROM AN ASSUMED INVERSE SQUARE DEPENDENCE ALONG HORIZONTAL AND VERTICAL LINES AT VARIOUS DISTANCES FROM THE SOURCE AT SITE 68




10 Millimeters to the Centimeter

FIGURE 10

DEVIATIONS FROM AN ASSUMED INVERSE SQUARE DEPENDENCE ALONG BEAM CENTER LINE AT SITE 68

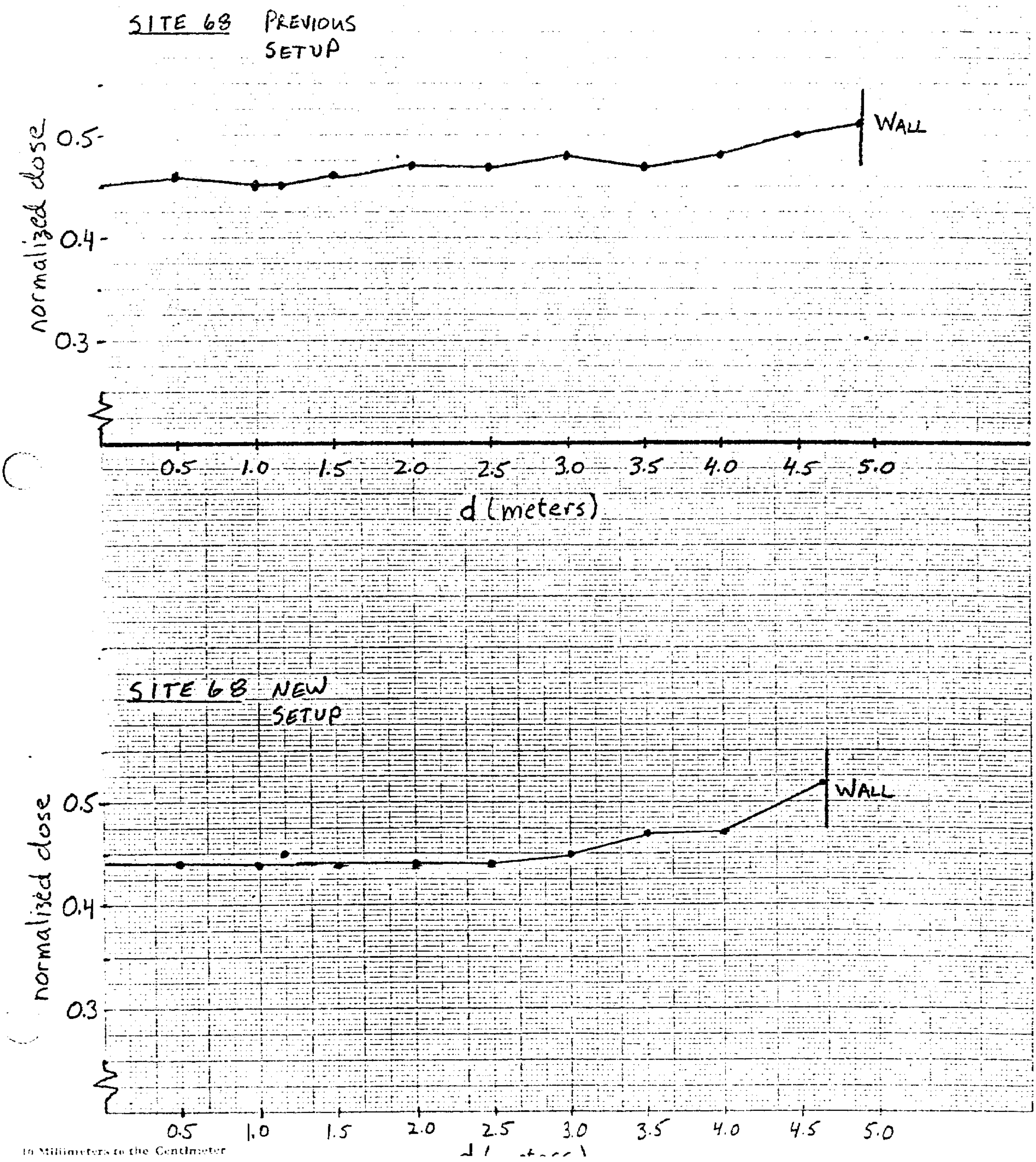
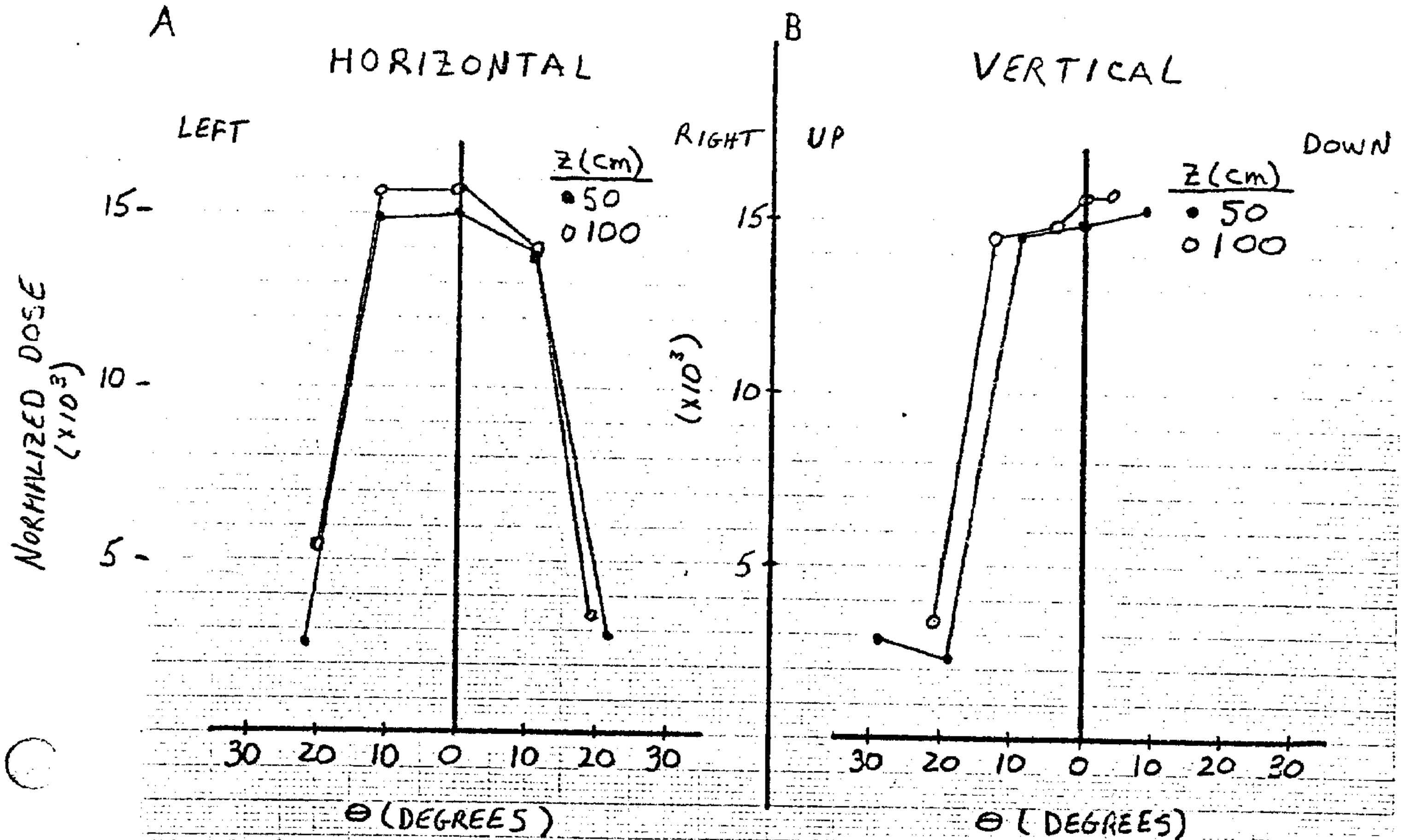


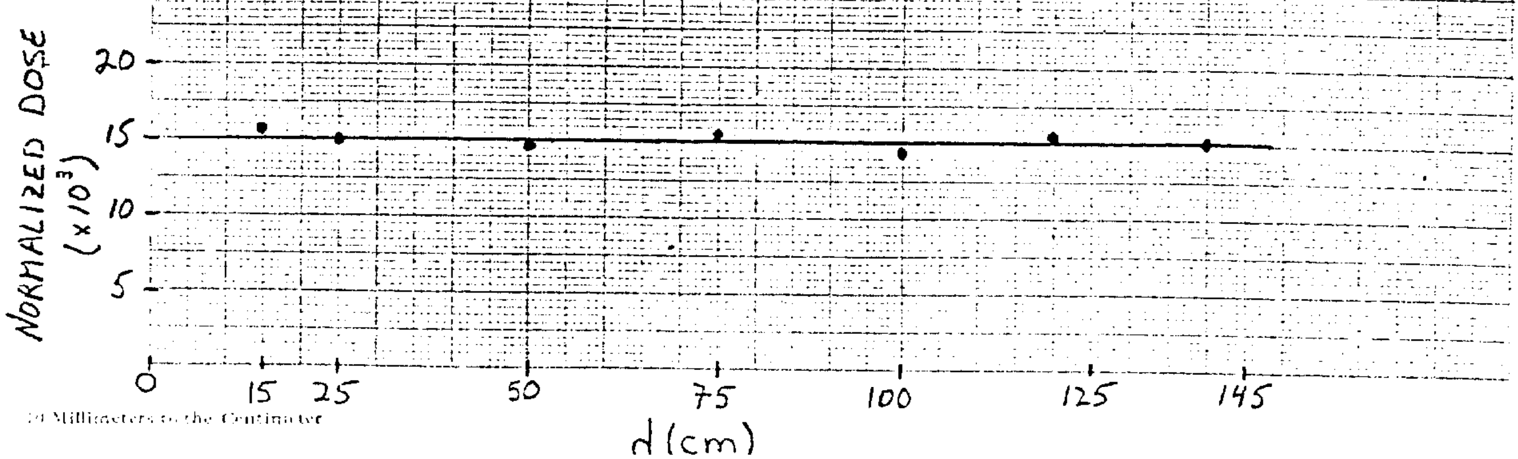
FIGURE 11

DEVIATIONS FROM AN ASSUMED INVERSE SQUARE DEPENDENCE ALONG HORIZONTAL AND VERTICAL LINES AT VARIOUS DISTANCES FROM THE SOURCE AT IMAC




C

DEVIATIONS FROM AN ASSUMED INVERSE SQUARE DEPENDENCE ALONG BEAM CENTER-LINE AT IMAC



# APPENDIX I

## Radioactive Sources

| Site 68 | IMAC |
|---|---|
| Cs-137 (137-8.1-1) | Cs-137 (137-5.4-2) |
| 135 Ci (2-1-73) | 370 mCi (2-8-72) |

## HARSHAW 2000 B/D TLD SYSTEM EQUIPMENT

Harshaw model 2000 D TL detector

Harshaw model 2000 B Automatic Integrating Picoammeter

Digitec 6110 Digital Recorder

Fisher Isotemp Oven set at 104°C

Thermolyne Type 2000 Furnace set at 400°C (model F-C2025p)

# APPENDIX 2

## Procedural Checklist for TLD Reader System

I. AC Power

- A. 2000 B/D Power ON for 3 hours minimum
- B. Printer Power ON

II. Utilities

- A. Cooling Water
  1. Secondary system main valve ON
  2. Primary pump ON
  3. Adjust flow to 300 ml/min (rotometer setting 36)
- B. Vacuum Pump Power ON
- C. Nitrogen Gas
  1. Bottle valve ON
  2. Adjust flow to 3.5 L/min (rotometer setting 82)
- D. 2000 D Utility switch ON
- E. Allow 1/2 hour for warm up

III. 2000 B Picoammeter

- A. H.V. check and adjust for 600 Volts
- B. Zero check and adjustment
- C. Current suppression adjust
- D. Operational Settings
  1. Meter switch to CURRENT
  2. Range Switch to AUTO
  3. Multiplier Switch to X1
  4. Time Set to 10 seconds

IV. Measurements

- A. Place loaded TLD tray on turntable
  Rotate counterclockwise to INDEX
- B. Set TLD thumbwheel switch
- C. Press READ on 2000D

Appendix A

JL 12/85
Rev. 1

## SOURCE PROJECTOR FACILITY

I. Physical Description

A. The source projector facility is located in the southeast corner of the basement of Site 68. The room is enclosed, except for a single door. The walls are lined with lead to reduce scattered radiation outside of the enclosure.

B. The radioactive sources installed in the projectors are Cs 137: 137-6.1-1 (1.2 Ci), 137-7.1-1 (12 Ci), and 137-8.1-1 (135 Ci). 137-6.1-1 and 137-7.1-1 are mounted in a dual projector, and 137-8.1-1 is in a single projector.

C. The dose rates available range from about 25 mR/hr at 4 meters for 137-6.1-1 to about 400,000 mr/hr at 1 foot for 137-8.1-1.

D. The source projectors are mounted on a stand, outside of the enclosure, that allows either the single source (137-8.1-1) or the dual source (137-7.1-1 and 137-6.1-1) to be rolled into line with a port for projection into the inside of the enclosure.

E. A detector positioning stand is roller mounted to floor rails along the beam axis inside the enclosure. The stand can be moved on the rails, via a remote drive mechanism, to vary the distance from the source to the stand. This distance can be adjusted and readout from outside the enclosure.

F. ANSI standard N543-1974 for "enclosed" type gamma-ray source installations, from NBS handbook 114 was used as a guide.

II. <u>Facility Safety Features</u>

A. The sources are locked with their combination locks when the sources are not being used.

B. The door to the enclosure is locked with two lock-on-closing type spring latches. The construction of the latches is such that opening the door from the outside requires the use of two keys, one for each lock. The inside of the door has knobs to turn for exiting, in case the door is closed while someone is inside.

C. The source projectors cannot be opened from inside the enclosure.

D. Signs are posted at the facility with the following messages:

1. Projector Facility
2. Authorized personnel only
3. Radiation area
4. High radiation area inside
5. 400 R/hr at one foot when source is open
6. Emergency information
7. Area survey maps
8. This procedure

E. The facility is interlocked. The exposed source will close if any of the following conditions are met: the enclosure door is opened <u>or</u> the interlock "test" push button is pressed <u>or</u> the manual source "off" push button is pressed <u>or</u> the source control is switched to "off" position <u>or</u> the preset time expires in timed mode. The interlock will <u>not</u> prevent the sources from being held open manually.

A loud siren is activated inside the enclosure when the source is open and either the door is opened <u>or</u> the test push button is pressed. Independent of the interlock system, a bright rotating magenta beacon is activated inside the enclosure when the radiation level at the downstream wall of the enclosure is greater than or equal to one half of the dose rate of the smallest projector source at that point. A light display is provided to indicate the status of the door and projectors.

III. <u>Personnel Requirements</u>

A. These sources are dangerous. The dose rate at 1 foot from 137-8.1-1 (exposed) is about 400 R/hr. Personnel exposure must be avoided.

B. Only personnel authorized by the Safety Section Head may operate the facility. The prerequisites for authorization are: attendance at the source training course, attendance at a demonstration of the source facility, and signing a document stating that they have read, and will obey these procedures.

C. The facility may be used with one or two operators. If the facility is to be used with one operator, <u>no</u> one else may participate in the experiment. If the facility is to be used with two operators, others may participate in the experiment. When using the two operator mode, both operators are required to be present when entering the enclosure, to be sure that the projectors are closed. Both operators are also required to be present when opening the projector, to make sure no one is in the enclosure, and that it is secure. During operation, the operator(s) must stay at Site 68, except as stated elsewhere in this section.

D. The operator(s) and all others taking part in the operation must wear: film badges, dosimeters, and digidoses.

E. All other personnel at Site 68 must wear film badges.

F. A sign stating that the projectors are being used must be posted across the inside vestibule door at the west entrance to Site 68. Signs are permanently posted at the entrances to the first floor southeast corner room stating that during facility operation the dose rate may approach 100 mR/Hr.

G. No one is allowed inside the projector enclosure when any of the sources is exposed.

H. The projector enclosure door must be closed and locked when a source is exposed.

I. In single operator mode, the operator must possess both enclosure keys. In two operator mode, each operator must possess an enclosure key.

J. Entry to the projector enclosure, while the facility is not in use, is permitted, provided that the person(s) make sure that the source projectors are in the closed position and are locked.

K. Unattended use of the facility during working hours is permitted under the following conditions: All other requirements of this procedure must be met. The operator(s) must keep both enclosure door keys, so that no one else can enter the enclosure. A sign must be posted at the facility indicating the operator(s) name(s), extension number(s), and pager number(s).

L. Unattended use of the facility during off-hours is permitted under the following conditions: Prior approval of the Safety Section Head is required. All preceding requirements must be met. In addition, the home phone number(s) of the operator(s) must be displayed on the sign, along with their name(s), extension(s), and pager number(s). Also, for this mode of operation, the Communications Center Dispatcher (x3414) must be notified of the situation, so that the Dispatcher can warn anyone needing to enter Site 68 of the danger. The Communications Center Dispatcher must also be notified when the operation is over.

M. Prior approval for variance from this procedure is required from the Safety Section Head.

IV. Normal Operation

A. This procedure deals only with the sources and the facility. It is assumed that the operators will make arrangements for any other equipment required.

B. All the rules set forth in this procedure must be obeyed.

C. The first step of operation of the source projector facility is to make sure that the sources are closed.

D. Place the "Projector Facility in use" sign across the vestibule door.

E. Take the enclosure keys from their storage location. If there are two operators, each operator gets a key.

F. After making sure the sources are closed, the operator(s) use the keys to enter the enclosure and setup the experiment.

G. Upon leaving the enclosure, the operator(s) search and secure the area, making sure that both door latches are locked.

H. Select the source to use by rolling it into line with the port.

I. Unlock the projector(s) to be used. Select timed or untimed operation. Pull up on the operating rod to expose the proper source. Do not open both projectors at the same time.

J. Look inside one of the viewing ports to make sure that the beacon is on. Press the siren alarm push button to make sure that the alarm is working. This will also close the exposed source. This test need only be done once, for each source, at the beginning of each operating period. If both projectors will be used, repeat steps H, I, and J for the other projector.

K. Adjust the source to detector distance by turning the hand crank and reading the tape measure located beneath the source stand.

L. Perform the exposure.

M. Close the source by pressing its "off" push button. In timed mode, the source will close by itself when timed out. Operator(s) make sure that both sources are closed.

N. Operator(s) may now use the keys to enter the enclosure. Use a survey meter to make sure that the sources are closed.

O. After the operation is done, close and lock both source projectors. Enter the facility and survey the area to verify that the source projectors are closed.

P. Close the facility door and put the enclosure keys back in their storage location.

Q. Remove the "Projector Facility in use" sign from the vestibule door.

V. Check List

A. Before operation:

1. Make sure sources are closed.
2. Set up signs.
3. Have on film badges, dosimeters, digidoses.
4. Each operator take a key. Single operator keeps both keys.
5. Secure the facility.

B. At start of operation:

1. Make sure the source you are using is in line with the port.
2. Make sure beacon is on when source is open.
3. Make sure siren alarm test works and the sources close.

C. After operation:

1. Close and lock sources.
2. Enter the enclosure and make sure sources are closed, using a survey meter.
3. Close the facility door and return keys.
4. Remove signs put up previously.

VI. General Responsibilities

A. The person ultimately responsible for the operation of the source projector facility is the Safety Section Head (Larry Coulson).

B. The person responsible for safety matters in the operation of the source projector facility is the Safety Section Safety Officer (Sam Baker).

C. The person responsible for alterations, repairs, modifications, and improvements to the source projector facility is the team leader of the Electronic Development Team (John Larson).

D. The person responsible for the source projectors is the Source Physicist (Alex Elwyn). Also, the source physicist is responsible for lock combinations and for all extra keys to the facility.

E. The IMAC team is responsible for testing the interlocks and warning devices every six months.

F. The operator(s) (users) of the facility assume responsibility for the safe operation of the facility during times of operation.

VII. Emergency Procedures

A. Close sources, if possible.

B. Leave immediate area.

C. Call 3131 for help.

I have read, and will follow the procedures for use of the Source Projector Facility (Revision 1).

| Print Name | I.D.# | Sign Name | Date |
|---|---|---|---|
| John Larson | 1612 | John Larson | 1-9-86 |
| Frederick P. Krueger | 1782 | Frederick P. Krueger | 1-9-86 |
| Fremont W. Hartman | 3678 | Fremont W. Hartman | 1-9-86 |
| Thomas S. Anderson | 721 | Thomas S. Anderson | 1-9-86 |
| THOMAS A. GOLASZEWSKI | 1871 | Thomas A. Golaszewski | 1-9-86 |
| Scott D. Hawke | 6396 | Scott D. Hawke | 1-10-86 |
| ~~Alex Elwyn~~ | ~~5702~~ | | |
| ALEX ELWYN | 5702 | Alex Elwyn | 1/10/86 |
| W Salsbury | 6834 | W Salsbury | 1/10/86 |
| w.s. Freeman ~~W.S. Freeman~~ | 5986 | W.S. Freeman | 1/10/86 |
| RICHARD ALLEN | 5559 | Richard Allen | 1/13/86 |
| PEDER YURISTA | 4699 | Peder M. Yurista | 1/15/86 |

Source Projector Facility Procedure (Revision 1)

Reviewed By: Samuel D. Baker — Jan. 6, 1986
Safety Officer — Date

Approved By: Larry Coulson — 1/9/86
Section Head — Date